

ATOMIC WEAPONS RESEARCH ESTABLISHMENT,
FOULNESS, ESSEX
COLD WAR RESEARCH & DEVELOPMENT SITE
SURVEY REPORT

Wayne Cocroft and Sarah Newsome



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FOULNESS
ESSEX
SURVEY REPORT**

Wayne D Cocroft and Sarah Newsome

NGR: TQ 98 91

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ISSN 1749-8775

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SUMMARY

The former Atomic Weapons Research Establishment, Foulness, is located on the north shore of the Thames Estuary, 9km (5½ miles) north-east of Southend-on-Sea, centred at TQ 98 91. It is amongst a handful of sites in England associated with the development of nuclear weapons and investigations into their effects. Internationally, such sites are rare, especially those associated with the pioneering stages of this technology. The site's history spans the full duration of the Cold War and research was undertaken within the establishment on all Britain's service nuclear weapons. A notable feature of the range is the building specially constructed for the assembly of Britain's first atomic device that was successfully detonated at Monte Bello, Australia in October 1952. This report describes the evolution of the local landscape up to 1945 and the physical development of the establishment. It also places its structures within the historical context of the development of Britain's Cold War nuclear weapons programmes.

Shoeburyness range is an active military test area and there is no public access.

CONTRIBUTORS

The field investigation was carried out by Wayne Cocroft, Sarah Newsome and Stephen Miles. Helen Winton undertook the air photographic transcription and the accompanying description is incorporated in this report. Professional ground photography was taken by Steve Cole.

ACKNOWLEDGEMENTS

English Heritage is grateful to Andrew Moffat for authorising access to the areas of Shoeburyness range administered by Defence Estates. We are also grateful to Elizabeth Crabbe and Ronald Shadforth of QinetiQ for facilitating our access to the range. Over the course of the project Bob Crump of the Foulness Archaeological and Conservation Society has provided much useful information.

ARCHIVE LOCATION

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DATE OF RESEARCH

Fieldwork was carried out during late 2006 and early 2007.

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I INTRODUCTION

The former Atomic Weapons Research Establishment, Foulness, is located on the north shore of the Thames Estuary, 9km (5½ miles) northeast of Southend-on-Sea. The site's history spans the full duration of the Cold War and research was undertaken within the establishment on all Britain's service nuclear weapons. It is amongst a handful of sites in England associated with the development of nuclear weapons and the study of their effects. Internationally, such sites are rare and especially those associated with the pioneering stages of this technology.

The investigation of the former AWRE site was originally conceived as part of a small national project 'Cold War, People and Place' that was designed to study four post-war defence research and development sites. To inform a possible Heritage Protection pilot study the project was extended to include an assessment of all the historic assets within the wider Shoeburyness Range. This work is presented as a separate report (Pearson 2006).

In preparation for the present survey, carried out during late 2006 and early 2007, a desk-top report of the area was undertaken in 2004 (Cocroft 2004). It was based on brief field visits to the range, the examination of primary documents in the National Archives, historic air photographs and Ordnance Survey maps, and the study of the few secondary sources relating to site. This report builds on this desk-top study and is based on detailed field inspections of all the buildings and features on the range, further documentary research, air photographic transcription of pasture within the former AWE enclave, and research to support land quality assessment studies.

The primary aim of this report is to describe the physical development of the former Atomic Weapons Research Establishment and to provide an outline of the historical context of the activities carried out within the site. Within the confines of a short report it is not possible to summarise decades of complex scientific investigations, information about which in many cases is still classified. For over 50 years it was also a place of work for hundreds of people. The site and its structures exemplify the physical business of scientific investigation in the late 20th century, and the development and manufacture of some of the most complex, expensive and controversial objects made in Britain – nuclear weapons. Shoeburyness range is an active military test area and there is no public access.

Notes

Throughout the report the title Atomic Weapons Research Establishment (AWRE) is used to refer to any activities prior to 1987, after this date its title was changed to the Atomic Weapons Establishment (AWE).

Within the report the buildings are referenced by their latest known numerical designation. Where the earlier number is known this will also be given, for example, **Administration Block A2/10**, where A2 is its current number and 10 is its previous designation. The current numbering scheme was probably adopted around 1955 and the earlier buildings renumbered at this time. In a small number of cases no official number could be found and feature numbers are prefixed by the letters EH.

2 TOPOGRAPHY AND LAND USE



Figure 1: Air photograph showing most of AWRE Foulness in 1970, to the top is the River Roach and to the left Shelford creek and the Middleway. UNT HSLEssex 0387 16 Sept 1970

The site of former AWRE Foulness (TQ 98 91) is located on Foulness Island about 9 km (5½ miles) northeast of Southend-on-Sea (Figure 1). Foulness Island is situated at the end of a long low-lying peninsular oriented roughly southwest to northeast. It is bounded to the west by the River Roach, which flows eastwards into the River Crouch and defines the northern limit of the island; to the south and east the island is bordered by Thames Estuary and its foreshore, the Maplin Sands. The western end of the peninsular is separated from the mainland by a number of creeks which form a series of islands; approaching from the west, Havengore Creek separates the mainland from Havengore Island; to its east New England Creek in turn divides it from New England Island. It is not a true island, as the creek defining its eastern side, Shelford Creek, was

partly filled during the early 1950s to provide extra land for trials work.

To its east of Shelford Creek is Foulness Island, the largest of the islands, stretching for about 8km (5 miles). It covers 2554 hectares (6,310 acres) and is almost level varying in height between 0 and 3m (10ft). Most of Foulness Island lies beneath the high tide level and sea defences have played a vital role in safe-guarding valuable farmland. During the middle ages it was made up of about 13 marshes, each of which was probably protected by its own sea defences. The first sea walls were recorded in the late 13th century and were constructed to defend the original land area at the western end of the island. From the early 15th century, at the opposite end of the island, walls were also built to enclose the 'innings', areas of former saltings that were brought into pasture or cultivation (Smith 1970, 26-29). Archaeological excavations have revealed sections of medieval timber revetments, while more recently the earthen dykes have been faced with either stones or concrete.

The island's soils are composed of marine alluviums; those to the southeast of the road leading to Churchend are more silty than the clayey soils to its north (Soil Survey of England and Wales, 1983). In the past the island was famed for its arable produce, today it has a mixed agricultural regime of arable, and sheep and cattle grazing, but it is a farming economy that is required to take a subsidiary place to the military land use. The coastal grazing meadows coupled with the surrounding mudflats form an important wildlife habitat and fall within the Essex Coast Environmentally Sensitive Area (ESA) and are regarded as a Special Area of Conservation (SAC). The former AWRE enclave, now known as Fleet after a local watercourse, is a particularly important wildlife area, an environment partly created by the establishment's activities, which from the late 1940s have restricted the agriculture regime to grazing. Most of the land within its boundary is designated as a Site of Special Scientific Interest, with the exception of the Headquarters Area, the Explosives Storage Area and the fenced ranges. The area is of recognised national and international importance as a winter feeding ground for waders and wildfowl, and is also a valuable breeding site; in addition the area supports many unusual plants and invertebrates.

Historically, Foulness Island has always been 'an area of both geographic and perceptual remoteness' (House of Commons 1990, 80). Until the early 20th century it was accessible only by boat or along an inter-tidal track across Maplin Sands, known as 'The Broom Way' after the withies that marked its course. This separateness was reinforced from the 19th century by the development of Shoeburyness Range by the War Office for weapons testing, which gradually spread northeastwards to include Maplin Sands and ultimately Foulness Island. Access to the range was strictly controlled both to ensure public safety and to conceal the work being undertaken. This secrecy was further reinforced prior to the Second World War, 1939-45, with the commencement of research involving the static detonation of bombs. Security was again increased after the war when work associated with the atomic bomb began, the Atomic Weapons Research Establishment (AWRE) becoming a separate enclave within the range.

Foulness was first mentioned in the late 12th century, when a place *Fulenesse* was recorded. The name was probably derived from the old English *Fugla-næss* - wild

birds' ness (Reaney 1969, 183). It is the largest of the area's islands and until the mid-16th century Foulness Island was divided between five mainland ecclesiastical parishes, Sutton, Rochford, Shopland, Little Stambridge and Little Wakering. Probably due to the distances to the parish churches, by 1386 a chapel was recorded on the island, which survived until the mid-16th century Reformation when the island became a single parish (Smith 1970, 23). Economically, throughout the middle ages the island provided valuable marshland grazing for flocks of sheep in turn supplying, milk, butter, cheese, wool, fleeces and meat. The coastline was also a valuable inshore fishery and oyster beds were developed on some of the creeks. During the post-medieval period the emphasis moved towards arable cultivation and the supply of wheat for the London market (Smith 1970, 9-16).

By 1840, the settlement pattern of the area later occupied by the Atomic Weapons Research Establishment was a mixture of small farm complexes and scattered cottages (Ordnance Survey, 1840). After this date there was a gradual loss of cottages and farms, which may be linked to a decline in agricultural employment, though, between 1870s and 1890s the coastal economy expanded with construction of a series of rectangular oyster beds at the northern end of New England Island. Within the AWRE area most of the farms and surviving cottages probably remained occupied until the Second World War. From air photographic evidence, during the war most of this area appears to have been

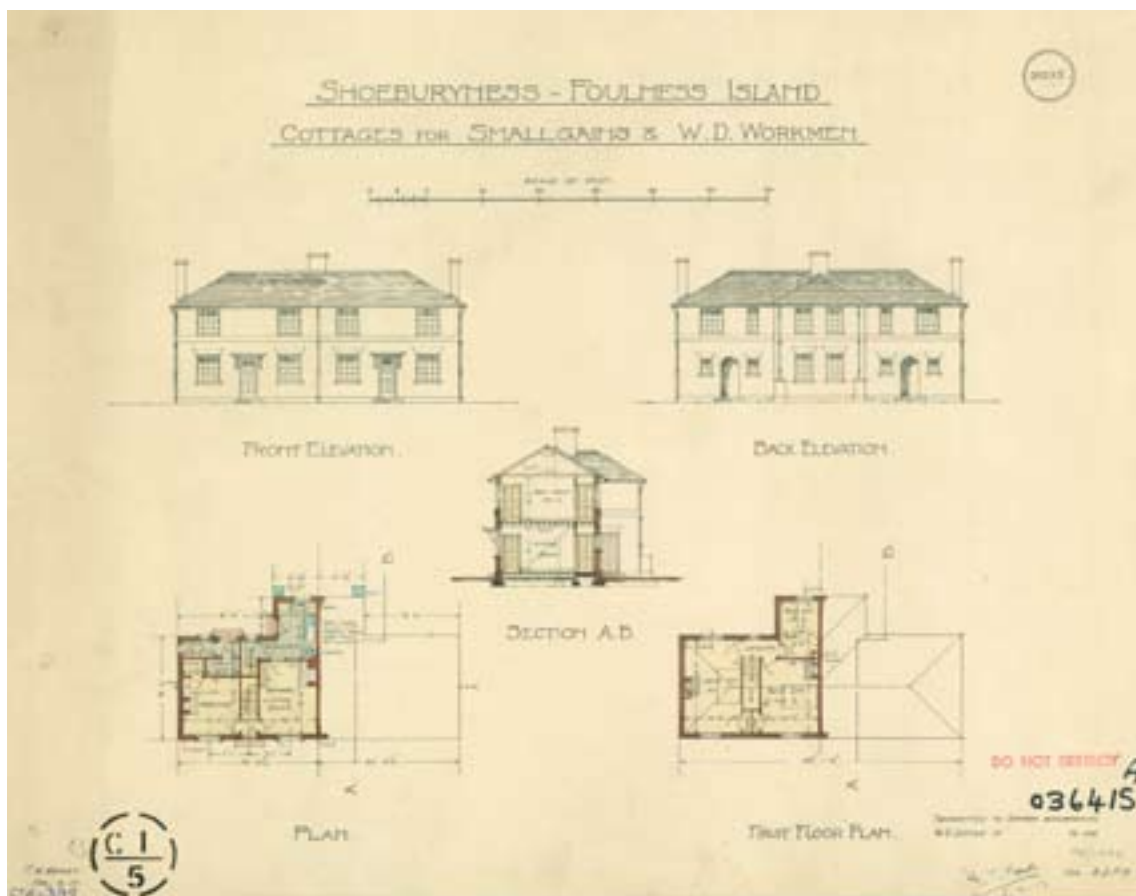


Figure 2: War Department design drawing for cottages to be erected at Smallgains Farm 1917. NMR MD/95/61746

used for scattered military storage, often centred on the existing farm complexes. New Marsh Farm probably remained occupied until the late 1940s, and from that date the area has been grazed by absentee farmers.

Prior to the 20th century access onto the northern shore of Foulness Island was from a series of quays on the Rivers Roach and Crouch; on the southern shore the approach was along The Broom Way. This route leaves the mainland at Great Wakering Stairs and runs for about 8.5km (5¼ miles) parallel to the coast, about 400m (1310ft) from the shore, and connects to five headways on the island. The route is only passable at low water and from the late 19th century access to it was further restricted by the use of the sands as an impact area for artillery shells. In 1913 the War Office announced that it would build a new road to provide access to the island when the Broom Way was under fire. This road, known as the Foulness Road, was completed in 1922 (Smith 1970, 41). The new road was not shown on the 1934 edition of Ordnance Survey map, probably because it was regarded as a sensitive military feature. The road begins at Landwick Gate to the east of Great Wakering, it then passes over Havengore Island and New England Island. From the eastern side of Havengore Island the road is straight and roughly bisects Foulness Island leading to the main settlement of Churchend. This comprises a 19th century church *St Mary the Virgin* in early English style by William Hambley (Pevsner, 1954, 184), a public house *The George and Dragon*, and a number of farms and cottages. With the coming of the new road this settlement underwent considerable expansion. During 1917 plans were drawn up for a number of new cottages to house War Department workers and policemen at Smallgains Farm and Churchend, at the latter a number of cottages still survive (NMR MD/95/01739 and 01748) Figure 2). To the northeast of Churchend is the small linear settlement of Courtsend. The remainder of the island is sparsely populated and is scattered amongst a number of isolated farms. The present population of Foulness Island is about 200 many of whom who derive their livelihoods from farming or the range.

3 PREVIOUS ARCHAEOLOGICAL AND HISTORICAL RESEARCH

The earliest recorded archaeological activity on the island was during the 19th century when seven or eight 2nd to 4th centuries Roman pots were recovered from a barrow, or red hill (a mound associated with salt making), at Loading Marsh, Little Shelford (Smith 1970, 8). Despite being a restricted area, since the 1970s archaeological discoveries on the range, and within the AWRE area, have been carefully documented by the Foulness Archaeological and Conservation Society (Crump 1985). The densest concentration of archaeological finds lie at the southwest end of the AWRE area on the eastern shore of Shelford Creek. Traces of Romano-British occupation of 2nd-3rd century date, covering about 30 acres (12 hectares) have been found. Specific features discovered include a ditch, midden deposits, cremations and associated objects in a red hill, burials, and a flimsy structure comprising a clay floor with walls made from stakes (Essex SMR 11220, 11222 {TQ 99SE 6}). Close to these features is another undated red hill (Essex SMR 11306). Part of this area where the cremations were found is a Scheduled Monument (Essex 164). In 2007, Defence Estates commissioned a geophysical survey of the scheduled Romano-British remains within the southwest area of Fleet (Masters 2007). This revealed anomalies, which probably indicate the presence of archaeological deposits. In peripheral areas due to later disturbances associated with the range's activities the results of the survey were inconclusive. At the eastern extremity of the surveyed area, although no anomalies were detected finds of Romano-British materials have been found.

As described above, Foulness Island is surrounded by an earthen dyke. Excavations in the 1970s, to the east of Shelford Creek, revealed timber and wattle work set in an earthen bank (Essex SMR 11221 {TQ 99 SE 8}). Radiocarbon dating indicated that the timberwork was 15th century, although there was some doubt if the bank represented part of the sea defences, or was a section of a raised roadway. To the northeast an undated wooden culvert, with a wooden cover, was discovered running across the line of the sea wall (Essex SMR 11366), and close to it, but probably unrelated, a gold Iron Age coin was found (Essex SMR 11367). Finds of medieval pottery have also been made in the vicinity of Pond Marsh cottage (TL 9860 9141) (Essex, HER 11352).

The history of the Shoeburyness range has been documented in *Guns and Gunners at Shoeburyness: The Experimental Establishment and Garrison* (Hill 1999). Due to the secrecy surrounding Britain's nuclear weapons programmes, little or no information was publicly available on AWRE Foulness prior to the 1990s. The link between Foulness and the atomic weapons programme was perhaps inadvertently revealed in 1954, when a job advisement appeared in *Nature* magazine seeking staff for AWRE Foulness (*Nature* 1954, ccxxviii). This led to a flurry of press reports connecting Foulness with AWRE (TNA: PRO ABI6/1552). These in turn led to a Parliamentary question by Lord Fairfax of Cameron, to which the Lord President (Lord Salisbury) replied:

The Foulness range has been used over some years by the AWRE for experimental work with ordinary conventional high explosives. The work is an essential step in the development of atomic weapons. The explosions are also used to study the effects on model structures and so provide valuable data for those forms of Civil Defence. I can say definitely that no nuclear explosions have been or will be made, nor will experiments be made into fission products or any other hazardous

radioactive material.

Hansard, 7 April 1954,

In the early 1990s, two synthetic works on nuclear weapons (Cathcart 1994: Norris *et al* 1994) briefly discussed some of the work that had taken place at Foulness. Also during that decade more official papers relating to AWRE Foulness were released to the National Archives, although many still remain closed. In 1999, as part of English Heritage's Cold War project (Cocroft and Thomas 2003) a number of structures within the former AWRE were photographed, this project also provided the national context for the establishment. A desk top report of the AWRE area produced in 2004 (Cocroft 2004) represented the first documentation of AWRE Foulness and the structures within its boundary. It is superseded by this report.

4 HISTORY

Military associations with Shoeburyness, and the sands to its east, began in the mid 19th century, when the Board of Ordnance acquired the area for the testing of ordnance and other types of munitions, such as early rockets (Skendelbery 1965, 214). A number have been recovered from Maplin Sands and are now on display at the Smithsonian Institution, Washington DC (Winters, 1990, 255-60). Their discovery indicates the possibility of other projectiles of historic interest lying buried in the mudflats. The first permanent Board of Ordnance experimental station at Shoeburyness was established in 1849 (RCHME 1995; Douet 1998, 137-9) in the area known as the Old Range. This area, part of which is a Conservation Area, was sold during the 1990s. Some of the buildings have been converted to residential use and other areas within the former establishment have been infilled with modern housing. During the remainder of the 19th century progressively more land was acquired along the seashore to the northeast of Shoeburyness, as the increasing size and ranges of guns demanded greater safety parameters (Hill 1999).

The wartime origins of the Shelford Range

Foulness Island, along with New England Island, was originally acquired by the War Office during the First World War, and during the Second World War the land on which the Atomic Weapons Research Establishment (AWRE) was built was used by the Armament Research Department (ARD). Prior to the Second World War their predecessors had used the northern end of Havengore Island, immediately to its west, for the static detonation of large high explosive bombs. The outbreak of war resulted in an increase of activity at Shoeburyness, and with the possible disruption to work that German air raids might bring, in 1941 another range was acquired in the New Forest at Millersford, Hampshire (Pasmore 1993, 23), although some work on very large bombs continued on Havengore Island. Wartime activity on the northwest corner of Foulness Island included the construction of hutted encampments, perhaps for accommodation (Figure 3). In the late 19th century Great Shelford farm comprised two clusters of farm buildings and associated yards or boundaries. Probably at the start of the war the farms were given over to military occupation. To the west, north, and northeast of the existing farms temporary buildings were constructed. These included an arc of 11 curved asbestos huts interspersed with other buildings types and structures, including a tower. Other huts may represent accommodation blocks. The area was partly fenced and linked back to the main island road by two rough track ways. A number of scarred areas may suggest that the area was also used for ad hoc weapons testing. Shortly after the war the 1940s military structures and the farms were removed and the area became part of Range I. To the west of Great Shelford was another 19th century farm complex known as Little Shelford. By 1946, only the farmhouse survived; around it were traces of recently removed buildings and heavy scarring, which may indicate weapons testing. To serve the various wartime sites the War Department built a temporary sinuous road from Foulness Road to Smallgains Farm. After the war the road was cleared and its route reverted to pasture.

Other concentrations of activity, indicated by hutting and disturbed ground, lay to the



Figure 3: This view taken shortly after the end of the Second World War shows most of the area of the later AWRE range. Towards the bottom is Shelford Farm and associated wartime huts, this is now F Range. Towards the top left is Smallgains Farm, later the site of the Explosives Area, and to its left the remains of a 1944 Diver anti aircraft battery. RAF 541/1496 4350 10 May 1946 NMR RAF Photography.

northeast of New Marsh Farm, and to its west, perhaps at the site of Brickhouse cottage (TL 991 915), and around Smallgains. At Smallports, curved huts and a large area of disturbance 43m (141ft) by 27m (88ft 6ins) points to wartime military activity in the vicinity and they were perhaps associated with two possible temporary heavy anti-aircraft batteries to the northeast, and to the south of the later Explosives Area. The larger site comprised eight small areas of disturbed ground and the smaller site to its northeast four areas of disturbed ground. Their remains suggest that they may have formed part of the 1944 Diver Strip. This was the codename given to temporary anti-aircraft batteries established in the summer of 1944 to counter the threat from German V-1 flying bombs. Assuming that the batteries were Diver sites their operational life would have been no more than a few months. Other minor activity, probably small stores areas or *ad hoc* test areas, were scattered across the Range, represented by small groups of curved

asbestos huts and patches of disturbed ground. These were concentrated between the road and the site of Little Burwood (TL 9900 9101) and along the meandering drain between Smallgains and the site of Pond Marsh cottage (RAF 106G/UK/1445 4106, 4155, 1 May 46).

To the northeast of N Range was New Marsh Farm, post-war air photographs record the remains of three farm buildings and associated garden plots shown on 19th century maps. Surrounding these were groups of military buildings, including curved asbestos huts. Much of the ground around the farm showed signs of recent disturbance, perhaps caused by training or testing. Temporary roads linked this area to numerous groups of buildings and structures of varying sizes and design. There are two further clusters of buildings, one at the western end of the site extending over an area of 150m (492 ft) by 110m (360ft) and centred at TQ 9900 9154. Centred at TQ 9914 9153 is another large disturbed area 160m (525ft) by 140m (459 ft). The structures in this area are more dispersed and appear to have been abandoned by 1946.

Also probably associated with wartime military activities were three towers, about 4.5m (14¾ ft) square with an annexe about 2.5m (8ft 3ins) square. They were positioned at irregular intervals on the west side of Foulness Road, at TQ 9962 9164, TQ 9899 9048 and TQ 9862 8996, roughly corresponding with the later entrances to D Area, the main AWRE entrance and the track to New Marsh Farm. Air photographs indicate that the towers survived until at least the late 1950s, but were demolished sometime during the early 1960s. These appear to have been similar to the tower that survived in the Explosives Area until the 1980s.

Lying at the mouth of the Thames, Foulness Island was the first land that German aircraft flew past on route to London. To challenge this menace three heavy anti-aircraft batteries were placed on Foulness Island, one lying to the east of the entry to the Shelford Range. It was known as N26 New Burwood (TQ 9985 9057) and comprised four emplacements for 3.7-inch anti-aircraft guns and a large accommodation site of 45 huts. Immediately to its north was the site of a probable unrotated projectile, or rocket, battery, this probably dated from summer 1944,. Nothing survives of the battery at New Burwood except for the concrete remains of two gun emplacements (Nash 1998, 69). Further to the east at Churchend a T type radar station (TR 006 932) was erected, of which at least one building remains (Anderton 2000, 43).

Post-war 1945-1947

Under the terms by which the land at Millersford, Hampshire, was acquired, the Ministry of Supply was obliged to vacate the site by August 1947. To compensate for this loss the ARD proposed moving all of its detonation work to Foulness Island, to an area bounded by Foulness Road, the watercourses of New England Creek, the Middleway, the River Roach and a footpath running back from the river adjacent to the White House and back to the Foulness Road. The area acquired by the ARD covered about 420 hectares (1040 acres) at the west end of Foulness Island and was known as the Shelford Range, after the adjacent creek (TNA: PRO ES1/330). The area for the new range was initially surveyed in July 1945 and plans were drawn up for a new establishment. In preparation for laying out the new range virtually all the wartime buildings were cleared in addition to the surviving farm buildings at Great Shelford and Little Shelford.

Basic High Explosives Research

On 8 January 1947, within the Attlee government a small secret cabinet committee, known as Gen 163, took the decision that Britain should proceed with the development of the atomic bomb (Hennessy 2003, 44-49). The team put in charge of developing Britain's atomic bomb was led by William Penney, Chief Superintendent Armaments Research (CSAR), a physicist and a leading member of the wartime British Mission to the United States Manhattan Project that was responsible for creating the first atomic bombs. Penney had played a prominent role in the project, in addition to his scientific contributions, he also sat on the Target Committee, which discussed which Japanese cities should be attacked, and flew with the mission that dropped the bomb on Nagasaki to film its results (Norris *et al* 1994, 19). It wasn't until May 1947 that Penney was appointed to lead the British bomb project, responsibility for which was given to a specially created division of the ARD. To disguise its real function it was called Basic High Explosive Research (BHER), its title usually abbreviated to HER, which functioned as a secretive and autonomous section of the larger organisation. Initially, the team comprised 34 ARD scientists, a figure that quickly grew to a few hundred. Initially, its main activities were split between Fort Halstead, Kent (Figure 4) and the Royal Arsenal, Woolwich.

During June 1947 this team drew up the development plan for the production of a British atomic bomb. It was during this initial planning period that the new Shelford Range was transferred to the High Explosives Research (HER) project. Following the handover the development of the range became more urgent and extensive than previously envisaged.



Figure 4: Fort Halstead, Kent, Detonation Chamber purpose built in 1949 for the High Explosives Research team. Smaller laboratory sized experiments were carried out here before the larger scale trials at Foulness. (c) English Heritage DP060573

Nevertheless, despite the national priority of the project, in November 1947, William Penney was forced to write to Lord Portal, Controller of Atomic Production at the Ministry of Supply, complaining that buildings that were due to be ready by early 1948, would probably be delayed by 12 months (TNA: PRO ESI/267). Further delays were caused by steel shortages in 1951 and the disastrous floods of February 1952 absorbed further resources to make good the resulting damage (TNA: PRO ESI/268).

The acquisition of the Shelford Range by HER potentially left the ARD without any suitable facilities, when they too were carrying out 'super priority' work on warheads for guided weapons. Their activities were accommodated within the Shelford Range until the early 1950s, when Potton Island to the west was acquired by ARD and dedicated range facilities constructed. Drawings of Potton Island in the National Monuments Record, date to late 1957 and early 1958, but it is unclear if these represent design or record drawings (NMR MD95/01757-01761).

Bomb design

During the Second World War two different kinds of atomic weapons were developed in the United States. The simpler of the two devices was known as a gun type. In this weapon two sub-critical masses of uranium 235 were placed at either end of a long tube, or gun barrel. To create a detonation, an explosive charge propels one of the sub-critical masses into the other, which when combined form a supercritical mass from which a nuclear chain reaction can occur, in turn releasing a massive amount of energy in the form of an explosion. It was a gun-type device, known as Little Boy that was dropped on Hiroshima on 6 August 1945 (Gibson 1996, 86).

The second sort of bomb was known as an implosion weapon; it was a device of this form, code-named Fat Man, which was dropped on Nagasaki. In this weapon a core of fissile material, plutonium, was surrounded by tons of high explosive lenses. The bomb casing was ball shaped and measured about 5ft (1.5m) in diameter and fully assembled weighed around 5 tons (5.08 tonnes). The function of the lenses was to 'focus' the inward acting pressure wave, or implosion, that was used to compress the plutonium core, increasing its density by a factor of two. This forms a supercritical mass, making possible a nuclear chain reaction (Gibson 1996, 87-8). There were many challenges involved in the development of an implosion device. The high explosive lenses that surrounded the core had to be manufactured to very high tolerances with explosives of consistently high purity, which were then cast into complex shapes while avoiding the formation of air bubbles or cracks as they dried. Methods then needed to be devised to assemble the lenses so that the inward blast wave would exert uniform pressure on the core. For such an explosion to occur all the lenses needed to be fired simultaneously, which in turn required the development of advanced electronic firing systems. There was also the industrial challenge of producing enough plutonium, a man-made metal created in a reactor. Despite the complexity of an implosion type weapon, it offered many advantages and possibilities to the weapon designers (Cathcart 1994, 50-54). One important benefit was that it used far less nuclear material than the gun design – about 6kg (13.5lbs) of plutonium against 61kg (135lbs) of uranium 235.

At the end of the war knowledge about the implosion system was top secret, and after the United States passed the Atomic Energy Act (McMahon Act) in November 1946, Britain could no longer rely on the interchange of information with the United States on atomic matters. The concept was, however, known to the small group of British scientists, including William Penney, who had played a prominent role in the wartime British Mission to Los Alamos. Indeed, many members of the British Mission had made important contributions to the design of the implosion device, such as James Tuck who worked on the shape of the explosive lenses, and Ernest Titterton who contributed to the detonation system (Cathcart 1994, 55). However, of the 19 British scientists who worked on the Manhattan Project, only Penney worked fulltime on the British post-war bomb project, but he was also able to draw on the notebooks and recollections of other members of the British Mission. Even before the decision had been taken to develop a British bomb, Sir James Chadwick, the leader of the British Mission, had ordered the British scientists working on the project to keep notes on their research and the work being carried on around them. One of Penney's most important sources of information was Dr Klaus Fuchs, a German émigré, who was later exposed as a Soviet spy in February 1950. He had remained with the United States atomic bomb project until 1946; on his return he was a frequent visitor and lecturer at Fort Halstead (Arnold 2001, 74-5; Goodman 2004, 62-69).

Within the atomic bomb project the HER team initially had responsibility for designing and producing the high explosive lenses, the development of the electronics needed to detonate the bomb, and the construction of the precision metal casing that would hold all the components together (Cathcart 1994, 84). The new facilities at Foulness were to play a crucial role in the development of the bomb. To test the assembly procedures a mock-up weapon comprising concrete lenses, known as *Alfred*, was assembled in **Explosives Preparation Laboratory X6/23** (Pyne 2006). Ernest Mott and his team in the explosives section at the Royal Arsenal, Woolwich, produced the high explosives lenses. During the initial design stages lenses were sent across to Foulness for test firing, and as work progressed more and more lenses were joined together for test firing. In April 1949 a six unit trial was staged - the whole bomb comprising 40 separate hexagons and pentagons of high explosive (TNA: PRO ES1/330; Cathcart 1994, 119). Later a whole hemisphere, representing around 2.5 tons of explosives, was assembled and fired.

The early 1950s expansion of the Foulness Explosives Storage Area, coupled with the appointment of Ernest Mott as Superintendent at Foulness in 1954, may point to the transfer of explosive lenses work from Woolwich to Foulness.

The Hurricane test 1952

In 1952, the new establishment on Foulness Island played a central role in Britain's first atomic bomb tests, codenamed *Hurricane*. In late May or early June, the components for the bombs were brought together for assembly at Foulness from the principal manufacturers: the Royal Ordnance Factory at Chorley in Lancashire, Fort Halstead and Chatham Dockyard in Kent, the Royal Arsenal, Woolwich, and the Percival Aircraft Company, Luton. Ernest Mott and George Gallie from Woolwich led the assembly team, which included H S Weeks and a group of technicians, including Mr Hessen who was in

charge of metrology (Cathcart 1994, 182, TNA: PRO ESI/331, Pyne 2006). The building used for the assembly work was the Explosives Preparations Laboratory, Building No.23 (now X6) (Figure 5), a building that had been the subject to last minute modifications in November 1947 after the initial design drawings had been prepared (see below) (Cathcart 1994, 182-3, *pers. comm.* R Crump). In the lead up to the tests assembly work was practiced on the inert device, *Alfred*. These preparations culminated in the summer of 1952 in the assembly of the high explosive elements for the *Hurricane* test that resulted in the successful detonation of Britain's first atomic device. Recent research has revealed that up to three live devices, *Hero*, *Hengist* and *Horsa*, were prepared (Pyne 2006), the latter two named after two semi-legendary early 5th century Jutish warrior brothers, who along with their war band were invited to defend Kent from the Germanic tribes.



Figure 5: Explosives Preparation Laboratory X6, was 23, late in 1947 Superintendent Roy Pilgrim respecified the design of this building for its role in the atomic bomb project. In 1952, the United Kingdom's first live atomic device was assembled in this building. (c) English Heritage DP035925

On Thursday 5 June 1952 one or more of the devices were taken by lorry to Shoeburyness and then by barge to a war surplus river class frigate *HMS Plym* moored at Stangate Creek, Sheerness, Kent. *HMS Plym* was then escorted by the trials flag ship *HMS Campania* on her eight week voyage to the test site, the Monte Bello Islands, off the northwest coast of Australia. After their arrival a further eight weeks were spent erecting the structures and equipment that were to be subjected to the full force of the device and preparing the firing circuits and monitoring equipment. The fissile core for the device to be used in the trial was flown to Australia by Sunderland flying boat - it arrived on 18 September. A device was successfully detonated on Friday 3 October 1952 producing an estimated yield of 25 kilotons, 4 kilotons greater than the similar bomb

dropped on Nagasaki in August 1945 (Norris *et al* 1994, 25-6).

The range at Foulness was also used to develop the monitoring instruments and to train the personnel who would operate them during the overseas tests. Preparations undertaken included the detonation of an 8,000lbs (3629kg) charge on Shoeburyness range to test photographic equipment and the co-ordination of the observation teams. The signal to detonate the device was to be sent by cable, while data from the various observation points would be carried back to the control centre by state-of-the-art radio equipment. To practice the test routines firing signals were sent about 6 miles (10km) from Shoeburyness to the *Plym*, moored at Stangate Creek, Sheerness, Kent. As the date of the test approached more elaborate tests were conducted to synchronise the firing signal with the monitoring equipment, some involving the firing of a 64lbs (29kg) charge at Foulness (Cathcart 1994, 175-6).

In the early 1950s, one of the major concerns amongst defence planners was that the Soviet Union might try to deliver an atomic bomb in the hold of a ship. If detonated in a port or estuary the resulting tidal wave would greatly increase the area of devastation. One of the reasons that it had been decided to carry Britain's first nuclear device on board the *Plym* was to study the effects of detonating a nuclear weapon at sea. Closer to home to address this danger, 7km (4¼ miles) to the southwest of the AWRE range a boom was constructed at Pig's Bay to link the Essex shore to Kent, and thereby restrict movement into the Thames Estuary. The boom is a Scheduled Monument (35502).

Civil Defence and weapon effects tests

In addition to undertaking research to develop explosives and other components for use in nuclear weapons, some of the earliest experiments undertaken on the range were the investigation of the effects of nuclear weapons. During the war considerable knowledge had been built up on the blast effects of high explosives on many different structural types. After the surrender of Japan, teams of allied scientists, including a number from Britain, were sent to study the devastation caused by the atomic bombs dropped on Hiroshima and Nagasaki (Home Office and Air Ministry 1946; Penney *et al* 1970). One of the principal methods of studying blast effects was through the use of models that were subject to scaled-down blasts (Figure 6). Responsibility for the design and construction of the models initially lay with a team within the Ministry of Works, led by Dr Francis Walley, a veteran of the November 1945 British mission to inspect Hiroshima and Nagasaki (Home Office and Air Ministry 1946, iv; Walley 2001, 15-21).

William Penney, in an article describing a reassessment of the yield of the atomic bombs dropped on Japan, described the simulation of an air burst explosion against model buildings. The Foulness range is not named in the article, but it most likely that the experiment took place there.

The blast wave was produced by bare spherical charges of RDX/TNT, 60/40 (composition B) weighing 64lbs. The charges comprised two cast and machined hemispheres cemented together and centrally initiated by a no.8 detonator. The charges were held in a nylon net suspended from a cable slung between two masts 48ft high.

The height of the centre of the charge above the ground was 35ft (corresponding to 1890ft full scale). Guy lines adjusted the position of the charge with an accuracy of at least 3in (half the charge radius) (Penney *et al* 1970, 373-4).



Figure 6: Photograph taken during the great flood of February 1953, showing the two steel towers between which a high explosive charge was suspended. In the foreground are scale models of various buildings, which would be subject to a blast wave when the high explosive ball was detonated. RAF 540/999 105 2 February 1953 NMR (RAF) Photography.

During the early 1950s when the exchange of nuclear data between the United States and United Kingdom was severely restricted one channel that did remain open was the discussion of weapons effects. Research results carried out by Foulness staff was a crucial intellectual commodity, which could be exchanged with the United States, and thereby maintaining links with its nuclear science community. The British scientist Solly Zuckerman had been approached by the United States Air Force as early as 1952 to discuss the biological effects of blast (SZ/BUF/3/1 Zuckerman 9-12-55). The 1954, United States Atomic Energy Act revised certain aspects of the 1946 legislation, including the exchange of information on weapons effects (Twigge 1993, 40-43). At a 1957 Tripartite conference between Canada, the United States and the United Kingdom, on the effects of atomic weapons, known Foulness staff were at the fore, including N S Thumpston, J K Wright, and C L Farror. E H Mott was also in attendance, titles of other papers suggest further contributions from Foulness staff (SZ/BUF/5 Buffalo (6) Agenda 9-9-1957).

The early British atomic trials were primarily concerned with perfecting the weapon's

design, although some testing of protective clothing and Civil Defence structures were incorporated into the tests. During the 1950s preparation for overseas trials and periods abroad were a regular feature of working life at Foulness. The experimental work on the island gave the personnel firsthand experience in handling large amounts of explosives and their detonation effects. Another important aspect of the establishment's work was the development of monitoring equipment, in particular pressure sensitive transducers and the preparation of cabling.

Information was also required on the effects of blast on the human body. In 1953, on the suggestion of Penney, the War Office approached Solly Zuckerman, then professor at the Department of Anatomy at the University of Birmingham, to undertake this work on its behalf. It was an area where he had particular expertise having carried out studies into the effectiveness of wartime bombing and nature of the injuries it caused (Zuckerman 1977, 119-121). Given AWRE's expertise and facilities for simulating blast waves, in particular long duration blast waves associated with atomic explosions, its co-operation was crucial for the success of this work.

Trials at Foulness began in late 1954 and continued into early 1955 comprising experiments with live rabbits and mice in the atomic blast simulator and exposing caged rabbits to ground blast (SZ/BUF/3/1 Zuckerman 9-12-55, Zuckerman 1988 173-6). A year later proposals to carry out trials with medium-sized animals at Foulness were met with consternation by AWRE staff. Locally, the Deputy Senior Superintendent C L Farrow was concerned about possible adverse local reaction to the use of live domestic animals, coupled with recent criticisms about blast damage to houses and the rumours of radioactive experiments (SZ/BUF/3/1 Memo 9-2-56). In an attempt to expedite the matter Zuckerman wrote to William Cook, Deputy Director of Aldermaston, who was also uneasy about the use of goats, 'due to the absolute necessity for safeguarding Foulness from violent opposition', and suggested using Porton Down's facilities (SZ/BUF/2 Cook 29-2-56). Probably, later in spring 1956, due to increased work commitments Foulness withdrew its assistance from the programme (SZ/BUF/3/1 undated memo). This was in part due planning for the forthcoming Buffalo trials, where two of Zuckerman's collaborators Professor Peter Krohn (a longstanding colleague from the war) and James McGregor oversaw the animal experiments (SZ/BUF/3/2 Operation Buffalo 1956).

Some of the personalities that may be linked with Foulness and the overseas trials include the most senior officials William Penney and Roy Pilgrim. Amongst the known Foulness scientists N S Thumpston, an expert on blast effects, was present at the 1956 *Buffalo* series of trials. Edward Drake Seager, a War Office employee co-ordinated the target response tests and worked closely with Foulness staff on these and later trials. This series of tests at Maralinga Field, Australia, included the first airdrop of a British atomic bomb, weapon effects tests on a variety of structures, military equipment and aircraft, and the indoctrination of large numbers of military officers into the realities of nuclear war (Drake Seager 1953, 87-91; 1994, 57).

In the 1963 Partial Test Ban Treaty banned the atmospheric testing of nuclear weapons. Underground testing was still permitted, but these were both very expensive and

required access to United States facilities. While some questions could only be resolved by live tests, weapon effects may also be studied by individually modelling the four main effects of a nuclear explosion - blast and shock waves, light and heat radiation, initial nuclear radiation, and electromagnetic radiation. Foulness with its large open range areas specialised in modelling blast and shock waves, and heat radiation, while Aldermaston focused on studying initial radiation and electromagnetic effects.

Experiments using radioactive and other hazardous substances

In common with other historic industrial and military sites former activities at AWE Foulness may have resulted in the contamination of the land and its buildings. Examples may include fuel and oil spillages around vehicle maintenance areas, traces of explosive residuals left in process buildings and firing areas, and asbestos building materials. In addition to these hazards that might be expected in former defence sites of this date, given the specialised nature of the research carried out at AWE Foulness other less predictable contaminants might also be found.

Periodically the question of carrying out experiments using radioactive materials was raised and in the early years it is clear that some tests were undertaken. In April 1950, the Admiralty Radiological Protection Panel carried out some trials using a shielded cobalt source to establish field laws (TNA: PRO ESI/330). Cobalt is a radioactive source with a short half life. An internal document written in the early 1950s admitted that 'some contamination has taken place', although its nature was not specified (TNA: PRO ESI/331). In response to the disclosure of the link between Foulness and Aldermaston revealed in 1954 (see *above*) scope for further experiments using radioactive material were severely limited by the Lord President's statement 'that no nuclear explosions have been or will be made, nor will experiments be made into fission products or any other hazardous radioactive material' (*Hansard*, 7 April 1954). This assurance reinforced the necessity of establishing a permanent proving ground at Maralinga in Australia. Here in the late 1950s and early 1960s hundreds of small trials concerned with weapons designs, and the testing of components and buildings were carried out, known as *Kittens*, *Rats*, *Tims* and *Vixens*. The *Vixen* series were concerned with weapons safety and the *Kittens*, *Rats* and *Tims* trials were designed to investigate explosive initiators and weapons assemblies. The latter tests used various hazardous substances, such as, beryllium, plutonium, polonium and uranium (Arnold and Smith 2006, 215-34).

In 1964, the question of firing large high explosive assemblies containing uranium and/or thorium at Foulness was raised. By this date not only was there the Lord President's assurance to be acknowledged, but also the recently signed Partial Test Ban Treaty that prohibited atmospheric nuclear testing. After consideration by a number of government departments it was determined that uranium was not a hazardous material and that its firing would not breach the treaty. The Foreign Secretary, however, was of the view that the experiments should not take place as it would weaken the Government's international negotiating position. With the approach of a general election he was also concerned about the political repercussions of a potentially contentious testing programme. It appears that this advice was followed; nevertheless, the question of firing devices containing uranium was again raised in 1972, in regard to the development of

the United Kingdom version of the United States XW-58 warhead used in the Polaris missile (Norris *et al* 1994, 49; TNA: PRO FCO 66/371). Again political opposition was voiced: both in regards to possible objections at home and also in relation to possibly comprising the protests the government was making about French nuclear tests in the Pacific. Additionally, by the end of 1972 there were indications that experiments within the closed bomb chambers at Aldermaston, probably using slightly smaller explosive charges, were producing the experimental data that was required (TNA: PRO FCO66/371).

One of the characteristics of the nuclear industry is its development and use of many previously exotic or unknown metals and other materials. One such metal is beryllium, a substance that was not widely available to industry until the late 1950s. Beryllium mixed with Uranium-238 is used as a tamper to surround the cores of some nuclear warheads (Wilkie 1984, 28-29; Norris *et al* 1994, 73) and it was probably in connection with this use and the minor trials at Maralinga that a number of experiments using beryllium were conducted in the early 1960s. In particular it may have been linked to the development of the United States Mark 28 warhead, details of which were supplied to the United Kingdom around this time (Norris *et al* 1994, 49). Initial experiments involving the firing of assemblies containing beryllium were undertaken in Australia and in the early 1960s four trial firings were conducted at Foulness (TNA: PRO I20/378). One of the consequences of these experiments was that beryllium was scattered across sections of the site. The main health risk from beryllium is through the inhalation of its fumes or dust, which can cause acute or chronic lung disease (www.llnl.gov) - a risk that may arise through soil disturbance. Accessible contemporary documents do not give precise details of the location of these experiments, it describes the area involved as being 1½ miles (2.4km) from Havengore Head and 3 miles (4.8km) from Fisherman's Head (TNA: PRO HLG120/378). These measurements would place the site of the firings along the southeast side of the AWE range, probably at Range I, which had previously been used for the detonation of large high explosive charges. Recent research has indicated that beryllium was used in F, N and S Ranges (Carl Bro 2006, 31).

Housing

In post-war Britain, the provision of housing was seen as a significant factor in attracting the right calibre of staff to work on often competing high priority government research projects. The prospect of decent housing was regarded as being especially important at Foulness, given the isolation and bleakness of the area, and also due to the shortage of houses in the area after London's wartime losses. In 1948, it was agreed with Southend Council that the Ministry of Supply would have access to 25 of 38 houses then being built by the council, however, the exact number available to the establishment was a source of constant dispute (TNA: PRO ESI/270). The War Department owned most of the houses on Foulness Island and some AWRE personnel lived in these houses (House of Commons 1990, 80). Hostel accommodation was also available on site in the pair of early 20th century cottages at Smallgains, which probably survived into the 1970s. Temporary overnight lodging on the island was also available in the *George and Dragon* at Churchend.

The thermonuclear era

In the middle of the Second World War, even before the first atomic bombs had been built, members of the Los Alamos team were considering the theoretical possibilities of a more powerful weapon based on nuclear fusion. In April 1946, progress on the nuclear fusion, or 'Super', weapon, was reviewed at a conference held at Los Alamos. In the audience were two members of the British Mission, Egon Bretscher and Klaus Fuchs, both of whom later went to work at the Atomic Energy Research Establishment, Harwell, Oxfordshire (Arnold 2001, 6-9). A memorandum on the future of HER activities at Foulness, written sometime in late 1952, around the time of the completion of the development of the Mark I warhead, began to predict the forthcoming research programme (TNA: PRO ESI/331). Details of the programme were characterised in cryptic terms, such as 'rather newer developments' and 'totally new fields', but may indicate that consideration was already being given to Foulness' role in the development of the H-bomb and other projects being developed at this time.

Administratively, in 1954 all atomic related work was transferred from the Ministry of Supply to the United Kingdom Atomic Energy Authority (UKAEA), within its responsibility for atomic weapons development was devolved to the Weapons Group, with its headquarters at Aldermaston, Berkshire and outstations at Foulness and later at Orford Ness, Suffolk (Cocroft and Alexander, 2009).

By March 1954, the Foulness establishment comprised about 50 buildings and was served by 3 miles (5km) of roads. Of the buildings, about half were laboratories or magazines, a tenth were offices and the remainder comprised stores, garages, splinter proof shelters, police lodges, and electrical transformer stations. In April, Roy Pilgrim, Superintendent Firing Range Foulness, was transferred to Aldermaston, where he later went on to become the trials director for the 1957 *Grapple* H-bomb tests. Ernest Mott, an explosives expert from the Royal Arsenal, Woolwich, replaced him. His appointment perhaps reflected a change in emphasis of activities carried out at Foulness as more explosives processing buildings were added to the Explosives Storage Area during the early 1950s.

On 16 June 1954 the Defence Policy Committee authorised the Minister of Supply to begin a programme for the production of hydrogen bombs, a decision finally endorsed by the Cabinet on 26 July (Hennessey 2003, 57-8). Politically, possession of the H-bomb was seen as vital in maintaining the country's position at the 'top table'. Its development was also crucial in continuing negotiations to re-establish closer links with the United States in the field of nuclear technology. The work was given greater urgency by American proposals to introduce a moratorium on further H-bomb tests (Arnold 2001, 108-127). This would prohibit atmospheric nuclear testing and thereby inhibit the British programme, which was already a few years behind the American and Russian developments.

The initiation of the H-bomb project over the next few years was reflected by an accelerating building campaign at Foulness (Figure 7). Soon after his arrival Mott drew up a plan for the rapid expansion of Foulness 'in anticipation of a considerably increased and broadened programme' (TNA: PRO ESI/269). After a hiatus of almost two years, two



Figure 7: The Headquarters Area in July 1956 to the top are a series of pre-fabricated workshops and laboratories that were hastily erected after the decision to proceed with the H-bomb. RAF 58/2011 0084 27 July 1956 NMR (RAF) Photography

new building phases were planned in 1954, including 16 new buildings and improvements to the site's infrastructure. The staff complement was also predicted to grow from 297 in 1954 to 408 by March 1955, about a quarter of whom were scientific staff (TNA: PRO ABI6/916). Expansion gathered pace through 1955 as six new building phases were planned, representing over twenty buildings, including large laboratories (Figure 8). As part of this build up and concentration of staff at Foulness, it was planned by September 1955 to move a research group from Fort Halstead into the newly built **Laboratory 73** (TNA: PRO ESI/919). Construction continued into 1956, but after this date building work was characterised by the addition of individual structures and the modification or refurbishment of existing buildings. The estimated cost of the mid-1950s building programmes was £500,000 (TNA: PRO ESI/331). Most of the documentation relating to later building programmes at AWE Foulness remains closed, nevertheless, a basic chronology of later structures may be established by the use of historic air photographs.

In 1954, discussions also began about the location of test facilities for the environmental testing of warheads, including vibration and temperature trials. But given that a safety



Figure 8: Laboratory LI was built in 1955 and illustrates many of the features typical of the mid-1950s pre-fabricated structures, including block panel wall construction, metal framed windows, and porch roofs supported by tubular steel arms. (c) English Heritage DP035968

radius of 550 yards (503m) was required around the test structures no suitable location was available at Foulness (TNA: PRO ESI/269). It was in this context that the first test structures were erected at AWRE Orford Ness, Suffolk. Facilities were urgently required to test the *Blue Danube* atomic bomb before a live airdrop in the autumn 1956 *Buffalo* trials. Most of the new establishment's work was associated with later programmes. Again in the late 1950s it was necessary to expand the environmental testing programme and after a number of sites, including Foulness, had been considered a memo in January 1960 noted 'that there was no satisfactory alternative to continuing at the Orford Ness site' (TNA: PRO ABI6/2228 E45 15/1/60). Shortly afterwards work began at Orford Ness on the erection of the pagoda-like Vibration Laboratories (Cocroft and Alexander, 2009).

The late 1950s

Little information is publicly available on the later history of research activity on the Foulness range, although many progress reports are listed in the National Archives' catalogue few have been released into the public domain. Many of the trials carried out at Foulness were specified by scientists based at Aldermaston and may remain within its closed archives.

On 1 October 1957, an explosion at Foulness opened what was to be a fateful month for Britain's nuclear programme; within a few days the West was shocked by the launch of the Soviet Sputnik satellite, and less than a week later a fire broke out in one of the plutonium production piles at Windscale (Arnold 1992). While 2,000 lbs (907.2kg) of waste TNT was being destroyed on the Burning Ground, after it had burnt for sometime

it was estimated that around 1,500 lbs (680.4 kg) exploded. This caused considerable damage in the Explosives Area where heavy teak doors were pulled off their hinges. The blast wave was so powerful that windows were shattered as far north as the Headquarters Area, but it is not reported if it had any serious effects on establishment's research programmes (SZ/BUF/3/2 Report on accident at Foulness).

The establishment's expertise in assessing ground shock also proved crucial in the lead up to the 1958 Test Ban Treaty negotiations, when an American scientist proposed that it might be possible to decouple the seismic signature of underground explosions. The project was led by Dr 'Hal' Thirlaway assisted amongst others by Eric Carpenter. Preliminary tests were carried out at Foulness prior to larger trials in Cornwall and Cumbria (www.subbrit.org.uk/rsg/features/operation_orpheus/index.html; Zuckerman 1988, 308-11).

The most complex British defence project of the late 1950s was the development of the intermediate range ballistic missile Blue Streak. In addition to the development of the warhead for the missile, AWRE was also consulted in regards to the design of the underground launching facility, or silo, in which it was proposed to emplace the missiles. In particular AWRE was asked to assess the vulnerability of the silo to nuclear attack, including the effects of the over pressure due to blast waves, displacement of the structure due to ground shock and the results of thermal and nuclear radiation (Dommett 1998, 2). One of Foulness's main tasks was to advise on the consequences of building the silos in different types of substrates. Surviving documents reveal that it was intended to carry out large scale firing trials at Foulness, using up to 2 tons of explosives to measure air-induced ground shock. Smaller scale firings were also planned for the shock tube (*see below*), along with desk based theoretical studies. Some of the work would also be carried out at the Suffield Range in Canada (TNA: PRO AVIA92/20). It is not known if any of this work commenced before the Blue Streak missile project was cancelled in April 1960.

Besides secrecy, the failure or abandonment of programmes might also lead to their historical obscurity. One example is a mid-1950s project to develop a small fission weapon *Pixie* that might be carried by a *Bloodhound* size of surface to air missile (TNA: PRO ES1/331; Moore 2004, 81).

From the late 1950s, the UKAEA also used the expertise of the staff at Foulness in the development of the country's civil nuclear power programme. The range offered facilities for the hazardous destructive testing of reactor vessels and for the study of the behaviour of different types of chemicals used in the reactors. Many of the technical papers describing these experiments are held by the National Archives.

Kings-Norton Report 1968

A government review of the atomic weapons establishments, carried out in 1968 under the chairmanship of the engineer Lord Kings-Norton, formerly Dr Harold Roxbee Cox, revealed that the main functions of the establishment were to provide open range facilities to support research work on implosion systems, to carry out hazard tests on nuclear weapons and their explosive components, and to study the effects of explosives (Kings Norton 1968, 19). Also around this time the future of the Shoeburyness range,

including Foulness Island, was thrown into doubt by the proposal to build London's third airport on Maplin Sands. The Kings-Norton report (1968, 19) identified this potential threat to Foulness, but there is no evidence that preparations were made to transfer its work to other establishments, as occurred with other Shoeburyness range activities. The project to construct the airport was finally abandoned by the Labour government in 1974. This decision was taken against the background of the 1973 oil crisis and the world economic recession that followed in its wake. There also had been strong objections on environmental grounds, due to the damage that would be caused to this important wildlife haven, and also the hazards that birds might pose to aircraft.

The 1970s and 1980s

From the period of intense activity of the late 1950s and early 1960s, the general trend over the following decades was one of gradually falling personnel numbers reflected by the decline in infrastructure projects. Although most of the establishment's later activities are likely to remain classified for the foreseeable future, it may be presumed that the heart of its work would have included the development of warheads for the WE177 series of free fall bombs, the submarine launched Polaris A3 missile and its improved successor Chevaline, as well as the current warhead for the Trident D-5 (Hawkings 2000, 58-60). Known studies in support of the Chevaline programme included work in the vacuum chamber on the gas dynamics associated with separation of the warhead, its carrier and decoys (Dommett 2008, 110). Also as part of this programme, during the late 1960s and 1970s, under the then Superintendent Pat Flynn, detonation research was carried out (Jones 2005, 184). The completion of the Trident project marked the end of almost fifty years of warhead development by the United Kingdom. The late 1980s also brought the beginning of a period of uncertainty for the establishment prompted by the proposal that private contractors should manage AWE (House of Commons 1990, 80-2). These later years were also characterised by a more diverse work pattern as the AWE range was used for a variety purposes besides nuclear weapons related research. In 1982, the Potton Island ranges; then operated by the Royal Armament Research and Development Establishment (RARDE), was closed and some of its work was transferred to the AWE range. In the early 1990s, in support of Operation Granby (Persian Gulf 1990-1991), experiments were conducted involving large amounts of burning crude oil (Carl Bro 2006, 23-24).

A brochure issued by AWE (AWE, nd) in the early 1990s, shortly before it was closed, provided an insight into the later capabilities of the range. In the Headquarters Area, in addition to providing the administrative support for the range, a wide variety of specialist engineering and scientific tasks were undertaken. These included an engineering section that comprised a welding and fabrication section and a machine tool room where components could be produced to very fine specifications. Dedicated equipment in this section included a shock tube to support the work of the Shock Physics Section. This area also contained laboratories for the Photographic Department, the Electronic Engineering Group involved in the development and maintenance of recording and test equipment, and the related Trials Instrumentation Group. Other activities required less specialised facilities, these included the Theoretical Physics Group, Mechanical Engineering Design and the Technical Graphics Unit.

Although the primary function of the range was to support Britain's nuclear weapons programme many of the test ranges also had other defence and industrial applications. Some of the facilities were specifically designed to measure nuclear effects. These included the thermal radiation facilities, to study the thermal action of a nuclear weapon on various materials and a 206m (660ft) tunnel to record blast effects. A number of the ranges were designed to study the results of the detonation of conventional explosives, some for use in nuclear weapons. Services offered included oblique impact and spigot-intrusion tests for the certification of new explosives by the Ordnance Board, Safety Service Organisation and the Sensitiveness Collaboration Committee (House of Commons 1990, 80). Since the late 1940s, AWRE Foulness had developed an expertise in the study of blast effects using specially cast explosives suspended in mid-air. Conventional explosives work was supported by test rigs to record the fragmentation patterns of exploding munitions and a strengthened firing chamber was available where projectiles could be fired into explosives to assess their vulnerability to small arms ammunition. Two ranges were devoted to experimental hydrodynamics where the properties of detonating explosives could be studied; one range specialised in the use of optical diagnostics and the other in high power radiography and electrical probe recording. The 75m (246m) long hypervelocity range used high speed photography and flash radiography to record the behaviour of projectiles. To support the explosives work the range also possessed specialised storage magazines and facilities for casting and machining explosives charges. Another section, the Structures Laboratory, was devoted to studying the effects of nuclear and conventional weapon attacks on a variety of full size and scale models. One of the latest complexes to be added in the mid-1980s was provided to replace the climatic test facilities at the Royal Arsenal, Woolwich. Its function was to simulate the different temperature and humidity conditions that military munitions might be subject to while in service, and to test their continuing effectiveness after such storage.

In its later years activities were split between two superintendencies, one dealt with weapons programmes and the other with support and nuclear effects. The weapons programmes included conventional explosives research, theoretical physics, hydrodynamics and proofing, and shock physics. The other group investigated nuclear weapons effects, structural models and trials instrumentation.

Closure

With the end of the Cold War, and the break-up of the Soviet Union in 1991, the centrality of nuclear weapons to the country's defence policy has lessened. In 1995 it was announced that to coincide with the introduction of the Trident submarines and their new generation of warheads that there would be a gradual rundown and closure of some of AWE's establishments (Fairhall 1995). Foulness, then employing about 200 people, was scheduled to close in 1998, although withdrawal was completed by late 1997. During that decade Britain's nuclear stockpile was also gradually reduced, exemplified by the withdrawal of the last Royal Air Force WE177s in March 1998 and the announcement in the 1998 Strategic Defence Review that the country will maintain fewer than 200 operationally available warheads. Coupled with a contraction of activity within this field, new methods of investigating the properties of nuclear technology have become

available, many based on complex computer modelling, which has made the physical replication of effects less important. Many of the facilities at Foulness were also outdated, and it was presumably argued that some activities could be more cost-effectively and efficiently carried out centrally at Aldermaston.

5 DESCRIPTION

As discussed above documented settlement on Foulness Island may be traced back to the Roman period. During the medieval and post-medieval periods the island was a valuable agricultural area and late 19th century maps record a number of farms and cottages in the former AWRE area. During the present investigation, due to health and safety concerns, it was not possible to undertake ground survey of the pasture areas. To record the traces of historic sea defences, lost settlements and former agricultural activity an air photographic transcription was undertaken of the former AWRE range (Figures 1 and 62). The results of that survey have been incorporated into the following discussion.

Agricultural remains

Remains of post-medieval drainage cover most of the western part of Foulness Island and a number of different forms of drainage and land improvement are visible on 1940s and 1950s aerial photographs. In the areas to the north of the Fleet and in the area occupied by the former AWRE headquarters buildings there are a series of rectangular fields. These are cut through by deeper curving drainage ditches, which appear to form part of an earlier system of drains, presumably 'formalising' and/or straightening streams that once crossed the area. The large rectangular fields are drained by a system of substantial parallel banks separated by deep ditches. This particular form of drainage appears to have been maintained until at least the 1940s when the large rectangular fields were mainly under arable cultivation. It is likely that the substantial banks and ditches formed part of a gravity drainage system which drained into the creeks through sluices at low tide and some of which are still in use today. The drainage pattern differs from the more irregular fields to the north and south of the ranges, by Little Shelford, in the southern half of the AWRE range. Some of these fields have an unusual system of regular sinuous narrow drains which may be some form of floated water meadow to provide early spring pasture.

Overlying much of the survey area is a series of narrow ridges. In parts of the area, for example to the southeast of the Headquarters Area, narrow cord-like striations are visible (see for example, RAF 58/1920 (V) 0055 Nov 1955). These probably represent the remains of comparatively modern ridge-and-furrow cultivation, perhaps produced by steam ploughing. Given the small and irregular shape of the fields in this area, this method of ploughing was probably used to improve the drainage of the pasture.

Parts of the drainage system was levelled by the construction of the AWRE range, and in some fields where the latest aerial photographs (1996) show arable they may have been partly levelled, but most appear to survive as earthworks.

Sea defences and causeways

Other earthworks in the pasture may mark the position of former flood defences or causeways. To the east of I Range and running towards K Site and between Shelford Creek and the Fleet is an earthwork bank about 16m (52ft 6ins) in width. Between TQ 9753 9063 and TQ 9765 9106 it may be traced for 440m (1443ft) before turning

eastwards for 120m (394ft) to TQ 9777 9105. It is unclear if this represents its full length as the southern end appears to stop at a post medieval or modern drain and any continuation beyond this point may have been ploughed level. At the northern end it appears to head towards an area of semi-natural earthworks where natural drainage features appear to have been slightly modified or straightened. The northern parts of the earthwork bank have been flattened by ploughing, but the southern portion survives in a reasonable condition. During the 1970s, a section of this earthwork was excavated revealing a substantial timberwork framework. For some of the main timbers dendrochronological dating suggested a felling date in the late 15th century (Crump 1985, 17-18).

A second earthwork bank is visible to its northwest, extending for 290m (952 ft) between TQ 9729 9120 and TQ 9755 9130. It may be traced from the site of the medieval or post medieval settlement at Smallports and heads in the direction of the Explosives Area. It terminates in an area of earthworks, perhaps representing modified natural drainage features. These banks may have marked subdivisions within the marshes, as well as providing strips of high ground to allow the livestock to escape during inundations.

Medieval and post-medieval settlement

Historic maps and air photographs indicate that the historic settlement pattern of the area was one of scattered farms and cottages (Figure 61). To the northeast, close to the southern bank of the River Roach, was White House Farm (TL 9887 9249). It was a substantial complex; by 1873 it comprised four brick and five wooden buildings with two large ponds and a small pier or jetty by the creek (Ordnance Survey, 1873). Around the time of the First World War it was visited by the Royal Commission on Historical Monuments, who noted it probably dated from the 17th century, but was unoccupied and falling into disrepair (RCHM 1923, 47). By 1946, White House Farm had been demolished, although a single, perhaps early 20th century building remained on the site. The farm's location was still discernible on post-war air photographs through faint traces of former tracks and boundaries, and trees that presumably once stood in its garden.

In the centre of the Range, close to the entrance to the Explosives Area, was another farm, Smallgains. This comprised three small buildings and to its east was a sub-rectangular enclosure defined by drainage ditches, which may have formed a garden area. By 1873 the three small buildings had been replaced by a substantial square farmhouse. Directly north of the farm was Smallgains Point and a landing stage providing access to the River Roach. In 1840, to the west of Smallgains, in the vicinity of an area named Smallports, were two or three small buildings. On the 1946 air photographs three buildings are visible in this area. The largest of the three buildings, 8m (26ft) by 4m (13ft) appeared to have a pitched roof, suggesting it could be a 19th century or earlier farm building. The other two buildings with curved roofs were probably military in origin. Another building in the area measured 6m (19ft 6ins) by 3m (10ft), it was perhaps a former agricultural building.

To the southeast of Smallports was Little Shelford (TL 9800 9062); by 1873 this comprised five brick buildings and one wooden structure. By 1946, air photographs show that

only the main farm building and its gardens remained. Some of the earthworks in this area appear to be a mix of man-made and natural features, some of which could relate to post medieval or possibly even medieval settlement. This area is obscured on the aerial photographs, but to the northwest of the farmhouse are parts of a ditched boundary. To the west of these features, there are hints of earthworks that could be traces of platforms, perhaps indicating former building locations. Further to the southeast was Great Shelford (TL 9846 9033), this was made up of what appears to be two farm complexes. The farm to the west consisted of five brick buildings and one timber structure and the one to the east a single large house, which might have incorporated attached outbuildings. A further farm complex lay about 1km (2/3 mile) to the northeast at New Marsh (TL 9933 9156), comprising perhaps two farmsteads. Between Great Shelford and New Marsh, on a meandering stream, were six cottages or agricultural buildings. At the southern end, were two structures lying within separate enclosures named Pond Marsh in 1840 and Little Burwood in 1873 (TL 9900 9101); to their northwest was an un-named building with a building to its northwest identified as Old Barn (TL 9885 9125); further northwestwards was another unidentified building and beyond it a building named as Pond Marsh in 1873 (TL 9860 9141). Between Pond Marsh and New Marsh Farm was a cottage named Brickhouse (TL 9906 9146) its name either suggesting its form or previous industrial activity in the area. Place-name evidence suggests that the settlements at Shelford and Burwood were of medieval origin (Reaney 1969, 183). The longevity of some of the settlement locations is indicated by the discovery of medieval shell-tempered pottery close to the site of Pond Marsh cottage (Essex HER 11352).

From the mid-19th century the settlement pattern was one of loss, so that by 1934 of the six cottages along the stream only Old Barn remained standing (Ordnance Survey, 1934). At the farm complexes the pattern is also one of gradual decline, by 1934 at Little and Great Shelford buildings had been demolished; at Great Shelford only the western wing of the eastern-most farm house was left standing. At New Marsh Farm there was no change to the plan form. In contrast at Smallgains, late in the First World War or shortly afterwards, the War Department erected a pair of cottages (NMR MD95/01746, Figure 2). The main farm building at Smallgains survived until the mid-1950s, while the adjacent cottages were used for some time as hostel accommodation for the range and stood until the 1970s (RAF 82/708 (V) 0222, 4 Feb 1953). Within the AWRE area New Marsh Farm probably remained occupied until the late 1940s when its occupants were moved out for security and safety reasons.

The AWRE Range



Figure 9: The main entrance to the AWRE area from Foulness Road in September 1999. (c) English Heritage BB99/15987

One of the attractions of Foulness Island for secret research activities was its remoteness yet relatively easy rail access from London to Southend. To further improve security the Atomic Weapons Research Establishment (AWRE) was located in a separate fenced enclave within the larger Shoeburyness range. This is enclosed by 9,700 yards (8870m) of fence, of which 5000 yards (4572m) of the original fence was reclaimed from the wartime Armament Research Department range at Millersford, Hampshire. Inside this boundary additional fences enclosed particularly sensitive areas, such as the Explosives Storage Area and the Headquarters Area (Figure 1). At the time of its closure in 1997 the AWRE area covered about 380 hectares (1320 acres) and comprised over 350 structures.

Access to the AWRE compound was along the main island road, Foulness Road. Entry into the area was at first controlled from a **Police Lodge 28e** and three other small unidentified buildings **28A**, **45** and **48**. The original entrance was probably remodelled during the 1950s and replaced by the present access. This consists of a symmetrical buff brick gateway, with flat concrete coping blocks topped by steel spikes (Figure 9). At its centre is a raised pier on which was a painted sign (now removed), comprising a Queen's crown over a circular scroll inscribed with 'Ministry of Defence PE' and at its centre the letters 'AWE'. To each side of the central pier are two openings closed by steel bars and to either side of these are the two double gates, the western one for entry and the easterly one the exit. Contemporary post-war industrial design principals are followed by the simple steel gates, with rounded corners and cut-out centres barred by steel

rods. These are painted light blue, the standard colour used within government research establishments.

Beyond the gate is a large floodlit inspection area; immediately inside the gate is a small glass fibre **Police Post G5**. To the east a large single-storey brick **Security Lodge GPPP01** flanks the area. This replaced the original **Police Lodge 28** and was probably initially constructed as an open bus shelter, which was subsequently modified by the addition of a search room and office accommodation. To its rear it is joined to a double-storey office building, behind which is a gun clearing butt. To the west is a prefabricated drive-through garage-like **Vehicle Security Inspection** building **G4**. To its rear is a barrier controlled from a small prefabricated **Observation Post G/OPI4**, which controlled access to the main spine road, Pilgrim's Way. This is orientated roughly southeast to northwest and runs for 2km (1¼ miles) to the Headquarters Area. To the south and running nearly parallel to the road is a deep drain known as The Fleet, which now gives its name to this area of the Shoeburyness Range. Spurs off this arterial road provide access to the various test ranges. To the west are four exits to Ranges C, F, I and J, and to the east are two exits to the Structures Laboratory and N Range and to the Explosives Storage Area.

The road names

Many of the roads on the range are named after personalities associated with AWRE's early activities. The main road, Pilgrim's Way, is named after Roy Pilgrim, the first Superintendent of the Foulness range, a veteran of the Bikini Atoll nuclear tests and a number of the 1950s British trials. In the Headquarters Area the close association between Foulness with the 1956 Buffalo Trials acknowledged with Drake-Seager Road. Edward Drake-Seager was from the War Office's planning staff and co-ordinated many aspects of these trials and other AWRE work, and was later Superintendent of AWRE Orford Ness. Another prominent member of the Foulness staff who was involved in the Buffalo Trials was N S Thumpston who is acknowledged in Thumpstons Way. The main spine road to F site, Farror Road, was named after the mid-1950s Deputy Senior Superintendent C L Farror. Other roads, such as Canfield Road, Oxney Way, Ingrave Road, Steeple Road may also acknowledge as yet unrecognised members of AWRE staff. Other roads such as, Dengie Road and Jaywick Road, Navestock Road are named after local Essex places.

The Ranges

The Armament Research Department initially acquired the Foulness range to provide a remote location to perform hazardous experiments. After its transfer to HER its priority work on the development of guided weapons continued for some years. Early activities included the detonation of large quantities of high explosives to simulate the blast wave produced by nuclear explosions, and trials of the conventional high explosives used within nuclear warheads. Experiments were also carried out using a variety of radioactive materials, including natural and depleted uranium, tritium, antimony-122, polonium and cerium-141. To ensure both the safety of the personnel and range structures the test ranges were widely dispersed. In common with other research establishments, the compartmentalisation of activities also served as a means of ensuring confidentiality between the different teams.

Some of the earliest tests were concerned with the detonation of large quantities of

high explosives. These involved tests to perfect the design of the explosives lenses that surrounded the core of the Blue Danube warhead and the development of instrumentation for use in the overseas weapons tests. The measurement of the pressure pulse, or air blast, produced by explosives was one of the key functions of the open ranges. To support this work, and overseas trials, a specialist Transducer Development Laboratory was established at Foulness in 1950. These devices are designed to generate electrical signals proportional to the pressures to which they are subjected. Simultaneously, the ranges were probably also in use for another national priority project - the development of guided weapons. It is believed that the focus for this early work was on Range I, sometimes referred to as the large bomb range, which occupied the area to the southwest of the site of Great Shelford farm. Under the latest designations this range includes C, D and F Ranges.

C Range



Figure 10: C area, to the right is the 1947 Office and Instrumentation building C1 and to its left a former Camera Position C2. (c) English Heritage

On entering the AWRE area C Range (Figure 64) is the first to be encountered and is accessed from a short spur, Canfield Road, on the south side of Pilgrims Way. The main structure in this area is the **Office and Instrumentation C1/I** building, formerly **Recording Building 2** (Figure 10). It is a robust brick structure with a flat concrete roof and windows protected by steel shutters. Adjacent to this building is a **Septic Tank C/SF26**. In common with all the others septic tanks on the range it was probably installed during the late 1950s. The Office and Instrumentation C1/I building was one of the first structures to be built and served the large bomb, or Range I, that lay to the northwest. On an air photograph a narrow line is seen running from this building to the centre of Range I, which probably represents a conduit for command wires or cables connected to monitoring instruments (Figure 11, RAF 542/201, 30 Jun 55, frame 102). As part of

the 1955 building programme, Phase XI, it was noted that as a result of a 'change in the emphasis in the work of the station' that **Recording Building 2** was to be converted into a **Chemical Analysis Laboratory X2**. To its southwest a few years later it was joined by a **Camera Position C2**, it too is brick built with a flat concrete roof, while its western side is protected by 5cm (2 inch) thick armour plate with a central camera aperture. To its south, is a later **Flammable Store C3**, which is constructed from breeze blocks.

D Range

Also initially associated with Range I is a similar group of buildings known as D Range (Figure 65), which is entered directly off the main island road, Foulness Road. It is accessed through a set of double gates through the main AWRE boundary fence via concrete track, Dengie Road. The first building encountered is a **Chemical Disposal Store D1/2**. This was one of the earliest buildings to be constructed around 1947 and was originally built as a **Recording Building** for Range I to its northwest. As with building **C1** command and instrumentation lines are visible on an air photograph running towards Range I. To its south is a **Septic Tank D/SF25**. Also probably constructed around this time was the **Experimental Store D2** that was originally built as a **Camera Position**. A later addition to the west is small breeze block **Store D3**.

F Range

F Range, initially known as Range I, and sometimes as Romans I, originally formed was along with Ranges B and C the Large Bomb Range (Figures 11 and 65). It partly overlies the site of Great Shelford farm and its associated buildings, and as described above, this area was also the site of temporary hutting erected during the Second World War (RAF 106G/1496 4350 10 May 1946). Both the farm and wartime huts were cleared to make way for Range I, which originally comprised two large firing areas to the southwest close to Shelford Creek (RAF 542/201 0102 30 Jun 55). F Range is entered off Pilgrims Way and is laid out along a central road, Farror Road, which is oriented roughly northeast to southwest and stretches for about 360m (1181 ft). Opposite the entrance to the range is a standard prefabricated **Observation Post F/OPI2**. On entering the first building to be encountered is an electrical **Sub Station SS/H** and close to it two of the original range buildings from the late 1940s or early 1950s, the **Office and Electronics Laboratory F1** (Figure 12) and the **Toilet and Mess Room F2**; to its rear is a **Septic Tank F/SF41**. These structures are similar to other range structures of this date, comprising brick walls with a flat concrete roof and steel shuttered windows. To the rear of **F1** is the steel-framed **Trials Assembly Building F42**. Also associated with **F1** are a number of prefabricated garage like **Stores, F7** and **F35** and to the southwest on Farror Road the **Workshop F23**. Also in this area are a number of shipping containers **F21-F27**, and **F36** that are used for storage purposes.

Southwards on Farror Road a short track to the west leads to a small cluster of buildings grouped around **F3** whose latest function is described as an **Ionising Radiation Facility F3** (Carl Bro 2006). **F3** was originally built as a range **Instrumentation and Recording** building; it is an L-shaped reinforced concrete structure, with an entrance protected by a sliding steel shutter on its northeast side. On the opposite side are 11 metal shutters



Figure 11: Range I, or the Large Bomb Range, later split into ranges C, D, F and I. In the centre two large scars may be seen formed by detonating large amounts of high explosives, faint linear lines from these areas mark the position of command and instrumentation cables. (c) Crown copyright NMR RAF (V) 542/201 0012 30 June 1955

that originally faced the range to the south. Around 1980 **F3** was converted into a small experimental point-blank firing area for tungsten and depleted uranium projectiles, an activity that lasted until 1989 (Carl Bro 2006, 12; Davidson 2006, 10). Associated with this phase of activity was an air filtration plant with an inlet **F17** sited to the southwest. This has been removed except for a concrete floor slab. In the northeast angle of the building was the outlet **F18**, this has also been removed except for a concrete plinth. To the east of **F3** a free-standing rectangular breeze block building **F19** was constructed, joined back to **F3** by a steel-framed and plywood corridor. To its south a rectangular Pendine block building **F11** was added; its walls are blank except to the south where there is a sealed aperture and immediately to its south a concrete plinth. It is unclear whether or not this aperture is an observation port, or if the plinth supported a piece of plant with a linkage back into **F11**. Pendine blocks, named after a range in Pembrokeshire, are large rectangular concrete blocks with lifting lugs on their top surface. In combination with armour plate they were widely used across the range to provide temporary shielding and to create heavily protected test areas or structures. To the southwest of this building a concrete path leads to a reinforced concrete **Toilet F5**, which was served by a **Septic Tank F/SF40**.

On the opposite side of Farror Road a short track leads to a **Magazine F7X** within a fenced compound. The **Magazine** is constructed from breeze blocks with a flat concrete roof; to its south a breeze block extension has been added to house the explosives cart



Figure 12: Office and Electronics Laboratory F1. (c) English Heritage

and a fire extinguisher.

To its southwest is another of group of structures centred on the **Stores F4/35**, formerly known as the **Firing Control Building and Instrumentation** (Figure 13). It is a large reinforced concrete rectangular building and was in place by 1955 and originally faced the Range 1 firing area to its southwest (RAF 542/30 0102 June 1955). This side of the building is protected by 25mm (1 inch) thick steel armour plate, which is heavily pitted by shrapnel scars. The plate is pierced by a rectangular slot with six observation ports, protected by hinged shutters. Close to this aperture is another smaller opening protected by a hinged metal plate. Observations were also made from a small steel turret projecting from the building's roof. On the rear side of the building are five cable openings protected by welded pipes and metal plates. To the north of **F4/35** is the concrete floor slab of a small **Store F21** and a steel shipping container **Store F37**.

Immediately to the southwest of **F4/35** are two small **Cable Terminal Buildings F12** and **F13**; **F12** comprises a single, square steel locker covered in reinforced concrete, with a battered side facing the southeast and a door to the northwest. **F13** is formed of three similar adjoining lockers. At some point their battered south eastern side was strengthened with an extra layer of concrete and, probably more recently, their doors have been removed. Subsequently, a semi-portable steel **Cable Terminal F/SF63** was placed alongside F13. Cabling from this cabin ran back to **F4**, removable plates in its sides allowed varying combination of cables to be deployed.

At the southwest end of Farror Road are a series of **Cable Terminals** that perhaps served firing areas on the open ground to their south. On the west side of the road is **Cable Terminal F14**. This was built in two phases and comprises standard steel lockers



Figure 13: Fire Control Building and Instrumentation F4, showing the heavily pitted armoured steel wall facing the range, armoured observation apertures and roof turret. (c) English Heritage

encased in concrete. Its battered southern side that faced the range has been further strengthened by armour plate. Conduits covered with removable metal plates run back towards the **Firing Control Building and Instrumentation F4/35**. Adjacent to this feature is a more recent concrete foundation for **Cabin S/SF46**, this has subsequently been moved close to **F9**. Also adjacent to **F14** is a movable steel cabin last used as a **Camera and Compressor House F/SF62**. On the opposite side of the road is another **Cable Terminal EH F**, this too is of reinforced concrete. This was also associated with Range I to its south and a conduit ran along the east side of Farror Road back to **F1**. Further to the south is another isolated **Cabin F/SF103**.

Opposite to **F4** a track heads southwards to another firing point, Range IB. At its centre is the **Trials Recording Facility F9**. This comprises two offset concrete blockhouses with protected observation ports to the southwest side. To the east of **F9** was probably a prefabricated garage-like **Store F/SF89**. This has been removed and only its floor slab remains. On the slab is a shipping container **Store F31** and adjacent to it a similar **Store F32**. Other modifications to this area include the repositioning of **Cabin F/SF46**, which is formed from a large cylindrical steel tank. To the south of **F9** was the **SWARF-X Radiography Facility F/SF64**, which it is believed was used to x-ray explosive events. It has been removed and no trace was found (Carl Bro 2006, 13). To the north of this trials area is a small **Electrical Terminal Pillar F10**.



Figure 14: Fire Control and Instrumentation Building F6 and Cable Terminal Building F16. (c) English Heritage

To the west of **F4/35** a track heads towards the **Firing Control and Instrumentation F6** (Figure 14) building, and beyond to an area known as Range 1E. This is a chisel-shaped concrete block house with a steel door to the northeast and its pointed end facing the **Firing Point F/SF82** to the southwest. On its southern face is an observation port and armoured cable outlet facing the **Firing Point**. On a concrete surface to the south of the building is the remains of a remotely operated winch that was used to raise explosives charges between the **Firing Point's** gantry towers. To the east of the **Firing Control and Instrumentation** building is a standard **Cable Terminal Building F16** comprising two steel lockers set in concrete.

The **Firing Point F/SF82** is a large open expanse of concrete with two vertical steel gantries to either side supporting a horizontal cross wire. At its centre is a pulley that was used to raise explosives charges off the ground. Surrounding the concrete are protective walls formed from Pendine blocks and movable steel **Explosives Lockers**, including **F29**. A feature of all the ranges is the presence of movable steel camera positions. Some are square steel cabins formed from armour plate, with bulk-head type doors, while others appear to have been created from steel fuel storage tanks, such as **N/SF 69** and **J/SF70**. Surrounding the **Firing Point F/SF82** are a number of such positions **F/SF103**, **N/SF75** and **N/SF105**.

I Range

I Range is also approached off Pilgrims Way and is served by a central access track, Ingrave Road (Figure 66). It is oriented northeast to southwest and runs for about 530m (1738 ft). At its southwest end is a T-junction, westwards it runs for about another 230m (750ft). Eastwards from the T-junction a track leads back towards F Range and the firing area **F/SF82**. Originally I Range comprised three separate areas, Range 4 at the northeast end of the road, Range 3 at its southwest end and Range 6.

At the entrance to I Range is a standard late 1940s **Observation Post I/OP7**, which controls access from the main range road. At the northwest end of this range are a number of buildings that were associated with underwater testing. The group is centred on the **Underwater Range I/SF3/27**, this comprises a now filled 38ft (11.6m) square concrete pond. In the centre of its southern side is a pair of inclined ramps spaced at sufficient width to accommodate a vehicle or trailer. At the centre of the ramp is a set of concrete steps. The ramp was probably used for hauling test items into the pool and is probably associated with a winch on **I14**. At the southwest corner is a large diameter pipe that leads back to the **Pumphouse I30**. On the east side of the pond is a larger brick built **Pumphouse I/SF15** with two 11cm (4ins) plastic pipes entering the pool. Abutting its south side of the **Pumphouse** is a brick locker. To the east of this pumphouse is a flat concrete surface **I/SF13** with groups of fixing bolts; these may have supported a tank and associated pumps and valves. To their west are six breeze block piers that may have supported a platform or tank. To the northwest of the pool is a small breeze block **Chlorination Plant House III**. To the south of **Underwater Range** is the **Experimental Control Building I14**. It is brick built with a single door and double window on its north side, its remaining elevations are blank, as noted above the winch on its east wall was probably used to position experimental devices in the **Underwater Range I/SF3**. To the east of **I14** is a **Chemical Store I/SF16**, a prefabricated garage like structure. To its east is a circular concrete platform 6.5m (21ft) in diameter with ten metal foot plates. A plastic pipe running back to **Pumphouse I30** probably indicates that it originally supported a tank. To the west of this group of buildings is a large pond that was also used for underwater testing.

Dominating the range to the east of Ingrave Road is the **Air Blast Simulator I/SF6** (Figure 15). It is essentially a large gun driven shock tube that was primarily constructed to model the blast effects created by a nuclear explosion. One of the reasons for the construction of the simulator was the 1963 Partial Test Ban Treaty that prohibited atmospheric nuclear explosions, which were used both to trial weapon designs and monitor the response of equipment and structures to such effects. The tunnel appears to have been built in three phases; air photographs confirm that it was begun sometime after August 1962 (RAF 5853/77 0056 August 1962). In 1965, discussions began on the construction of a simulator large enough to take a Chieftain main battle tank. Other equipment tested in the tunnel included aircraft, armoured and soft-skinned vehicles, missiles systems, and electronic equipment. By the use of mathematical scaling it might also be used to model the effects of larger explosions (Clare and Rowe 1974).

The simulator is oriented from southwest to northeast and measures 206m (676ft) in length and is constructed from a series of incrementally larger curved steel segments



Figure 15: Mid 1960s Air Blast Simulator I/SF6. (c) English Heritage BB99/15990

starting with 1.83m (6ft) segments at the southern end, increasing to 9.75m (32ft) at the opposite end. In its original form it was 6ft (1.83m) in diameter and this was enlarged by 8ft (2.4m) sections fabricated from secondhand steel chemical storage tanks, and incorporated a special section for testing buried structures. To this section was added a 16ft (4.9m) portion, this also included a pair of 27ft (8.2m) test sections mounted on rails and strong enough to carry a 50 ton (51 tonnes) tank. This extended tunnel then terminated in a concrete block and earth traverse, with a 3ft (0.9m) gap between it and the end of the tunnel. This phase of work was complete by early 1968 (Clare and Rowe 1974; RAF 543/4304, frame 0698, 14 May 1968). Subsequently the tunnel was enlarged by the addition of a 32ft (9.75m) wide section. This is sealed by rows of horizontally mounted scaffold poles, which allowed the shock wave to disperse without bouncing back into the tunnel. This section is lit by ten photographic lights set in fives along either side of the roof. Camera positions along the side the tunnel allowed the effects of the blast wave to be photographed. Monitoring equipment used in used in the tunnel included pressure transducers, strain gauges, load cells, thermocouples, and in the 1960s cine cameras operating at up to 12,000 frames per second.

The blast wave was originally propagated by firing a charge of Quarrex mining explosives in a pair of 9.2 inch naval guns mounted at the narrow, south western, end of the tunnel. This method was later superseded by wrapping a strand of commercial mining explosive cord around a polystyrene former suspended from the tunnel roof. This was assembled in a specially constructed garage-like, prefabricated concrete **Charge Assembly Building I/SF49** at the southwest end of the tunnel (Figure 16). Entry into the narrow section of the tunnel is through a steel bulkhead-type door that is closed prior to firing. Exhaust gases produced by the detonation of the explosive mining cord were removed by the **Exhaust Control Building I/SF27** and **Blast Tunnel Extractor Fan I/SF45**, which are located on its east side. Towards the northern end of the tunnel are two test sections, the narrower section 4.9m



Figure 16: Charge Assembly Building I/SF46, this view shows the polystyrene former around which a length of detonating cord was wrapped. Once assembled the charge was suspended in the tunnel and the bulkhead doors sealed. (c) English Heritage BB99/16000

(16ft) comprises two sections mounted on rails that may be pushed in and out of position. These were winched into place by a 5-ton winch housed in a **Garage I/SF65** located on the west side of the tunnel. Associated with this building is a prefabricated **Store I25**. The lights were controlled from a small prefabricated **Cable Terminal Building I24** on the east side of the tunnel. Along side the tunnel are a number of other **Cable Terminal Buildings I5, I6** and **I20**, these are simple breeze block structures with flat concrete roofs. At the northern end of the tunnel is a more substantial and probably more recent **Cable Terminal Building I18** and adjacent to it is a prefabricated **Store I/SF94** and small **Braithwaite Water Tank I/WT7**.

Opposite to these buildings a track leads to a complex of structures grouped around the **Instrumentation and Offices II/3** building (Figure 17). This is one of the earliest buildings on the range and was part of the 1947 Phase I development. The present building comprises two late 1940s structures, the **Main Recording Building 3** and the **Shock Tube Building 3A**, which have subsequently been joined together to form a single building. Typical of buildings of this date, it is a single storey brick structure with a flat concrete roof. It has metal Crittall windows with brick sills and concrete lintels, which are protected by steel shutters. On the opposite side of the track, perhaps connected with these structures, was a large square patch of cleared ground with two smaller areas to either side. To the southwest of this complex was the site of Little Shelford Farm and



Figure 17: Office and Laboratory 13, this building is typical of the late 1940s and early 1950s range control buildings with brick walls, a flat concrete roof and steel Crittall windows protected by hinged steel shutters. (c) English Heritage

its associated buildings that were cleared for the construction of the range. As with the contemporary buildings **CI** and **DI** a conduit for command or instrumentation cables is visible on an air photograph running back to centre of Range I (RAF 542/201, frame 102, 30 Jun 55). Modern notices above two doors on the **Instrumentation and Offices II** building read 'Clean Entrance' and 'Dirty Entrance' suggest that at some point the building may have been used to assemble explosive devices. To the west of this building is **Septic Tank I/SF29**. To the north of the **Instrumentation and Offices II** is a small detached breeze block **Explosives Locker IIX**. Adjacent to this structure is a prefabricated **Garage Store I21**. At the angle of the junction between Ingrave Road and the entry to this area is a structure described as a **Fork Lift Garage I10 (Figure 18)**. This description, however, does not correspond with the form of the structure. At its south eastern end is a tall steel-framed brick structure with a single tall bay closed on its northern side by sliding steel doors. The total height of this bay is 5.83m (19ft). To its west is a tall lifting frame constructed from square steel sections, which supports an I-section lifting beam. Beneath this frame is a square grassy area that may indicate the position of a filled pit. To the west of the tall bay is a self-contained electrical switch room and on the southeast side an brick outshot, a tap on its wall may indicate that it was used to house pressure vessels. The tall bay would seem to indicate that it was used to store tall objects held in a vertical position. The original function of this structure is unknown.

Returning to the south western end of the tunnel and opposite to the **Charge Assembly Building I/SF49** a track leads to an electrical **Sub Station SSD**. Close to the top of this track is the concrete floor slab of **I/SF50**, which probably represents the site of a prefabricated garage-like store. The **Sub Station SSD** is a brick structure with a flat



Figure 18: This building 110 was last used as a Fork Lift Garage, but was probably constructed for a more specialised function. (C) English Heritage

concrete roof and was constructed in two phases. Opposite the northern end of the track and adjacent to the **Charge Assembly Building I/SF49** there is an **Electrical Feeder Pillar I2**.

As described above at the southwest end of Ingrave Road is a T-junction and beyond this the roads runs westwards for about another 230m (750ft). At this junction is another group of early structures dating from the first construction phases in the late 1940s. On the northwest side of the track is a large brick built, single storey **Office and Laboratory I3** building. In the angle of the corner is another large structure **Experimental Building I4** that is formed from two smaller buildings that probably correspond to the earlier designations 4B and 4D (TNA: PRO ABI6/1777). At some point the two original buildings, 4B to the west and 4D to the east were joined by a single storey link to create single large structure. In a compound to its rear is a **Pressure Vessel I/SF12** and beyond this on the open ground a **Septic Tank I/SF39**. At the east end of **I3** is a concrete surface **I/SF14** with a number of concrete blocks that may have supported a lifting gantry. Beyond this building is another early structure the **Fire Control Building I7/4E**. Its original function was originally **Fragment Analysis 4E** that suggests it may have been associated with the early work by Armaments Research Establishment (ARE) on another priority project the development of warhead designs for Britain's first generation of guided weapons. This work continued on the Foulness Range until the development of their dedicated facilities on Potton Island in the mid-1950s (TNA: PRO ESI/919).

Opposite to **4E** later developments in this area include a **Garage Store I/SF4** and

adjacent to it a hardstanding **I/SF1.7** that was perhaps the base for another small structure. To the rear of the **Fire Control Building I7** is another group of more recent structures. It comprises a prefabricated garage-like structure the **X-Ray Service Building I13** and two near identical breeze block **Cable Terminal Buildings I17** and **I19**.

Following the main track westwards it leads towards an area originally designated as Range 3. On the north side of the track is a relatively recent prefabricated **Store I12** and adjacent to it a movable steel **Wernick Cabin I23**. Close to these features and also on the north side of the track is a movable **Compressor House I/SF28** constructed from steel plate and adjacent to it a small brick **Cable Terminal Building I16** and a breeze block **Explosives Locker I13X**. Opposite to this are a small brick **Cable Terminal Building I15** and a track that leads to the **Bulk Aluminium Powder Store I8**. This is a two phase brick structure, comprising an earlier **Fire Control Building** with a later rectangular brick building. The earlier building probably dates to the late 1940s and is identical to **J1** and **J2**. It is a rectangular building with wing walls, its south side is protected by armour plate, which suggests there was a firing area to the south between this building and Shelford Creek. At the west end of the track are two 6m (19ft 6ins) diameter concrete **Firing Points I/SF87** and **I/SF88**, both have traces of mountings for test equipment. Westwards beyond this area was Range 6.

J Site



Figure 19: J/OP3 this brick Observation Post with narrow observation slits is typical of such posts built in the late 1940s and early 1950s. (c) English Heritage



Figure 20: Fire Control Building J1. (c) English Heritage DP035952

J site lies immediately to the west of I site (Figure 66). Originally its central section was designated Range 3 and its western end Range 7. It too is accessed off Pilgrims Way; at the entrance to the range is a standard late 1940s brick **Observation Post J/OP3** (Figure 19). The main J Range road, Jaywick Road, is oriented northeast to southwest and runs



Figure 21 Compressed Air Launcher J/SF71, to the right is the steel container that housed the compressed air gun and to the left the Pendine block butt. (c) English Heritage

for about 400m (1300ft) before turning northwestwards for another 150m (492ft). The first building encountered on this range is the **Fire Control Building J1** (Figure 20). This structure has trapezoidal walls and is identical to **J18** and **J2**. Its western side is protected by armour plate, which implies that the original range was to the west. The building has subsequently been extended by the addition of a split-level brick building to the east. In its latest phase it was used as the control room for the **Compressed Air Launcher J/SF71** and there is a cable conduit that joins the two structures.

The **Compressed Air Launcher J/SF71** (Figure 21) is on the opposite side of Jaywick Road and comprises a large, movable steel container with a gun like barrel at its eastern end pointing to a set of butts created from Pendine blocks, earth and armour plate. Close to the **Compressed Air Launcher** is a movable steel **Explosives Locker J1X**. To the west is a crossroads. By the early 1970s the **Large Area Open-Range Thermal Simulator (LATS)** or **Thermal Radiation Facility J/SF20** had been constructed in the



Figure 22: Large Area Open Range Thermal Simulator (LATS) or Thermal Radiation Facility J/SF20. To the rear is the building that housed the powdered aluminium and liquid oxygen bottles and to its rear the platform on which test equipment was mounted. In the foreground is the movable platform on which manikins were placed. (c) English Heritage BB99/15986

southeast corner of the crossroads (MAL 49/73 0021 9-Sep-1973) (Figure 22). This facility was used to model the intense heat associated with the detonation of a nuclear weapon. Tests on smaller items were carried out elsewhere under laboratory conditions. The LATS structure allowed larger items of equipment such as trucks or helicopters to be tested, using a thermal source of finely divided aluminium and liquid oxygen to generate temperatures of up to 2700°K. The facility consists of a prefabricated shed which housed a liquid oxygen supply with four burners covered by removable caps mounted on its roof. To the rear of

the shed was a platform on to which equipment could be placed for testing, where it was subject to a burst of flame for a given duration of between 1 to 5 seconds. This platform was removed sometime after 1999 and before the present survey. On the opposite side of the track is a prefabricated **Observation Post J/SF18** and adjacent to it a movable platform about 3m square and filled with earth on which a manikin was placed to test the effects on military clothing and personal equipment. To its northeast is the **Thermal Radiation Simulator Workshop J/SF98**, a prefabricated garage.

The track adjacent to the **Thermal Radiation Facility J/SF20** leads to the **Instrumentation and Firing Control J2** building. This is another late 1940s trapezoidal-shaped building and has an armoured plate wall on its northwest side implying its range was to the northwest. It may have shared a range with **J1**. Subsequently, the range was reorganised and a prefabricated **Material Store J/SF54** was built to the northwest. Opposite this structure is the concrete floor slab of **J/SF69**, an **Observation Chamber**, which has been moved to F Range. To its southeast is the **Synergistic Rig Store J13**. This is a steel plate cabin containing compressor equipment and gas cylinders. Externally, along one wall, is a cover for cylinders.

In the northeast angle of the crossroads is a steel **Explosive Locker J16X** and at the end of the track a breeze block **Explosive Locker J8X**. To its north is a large concrete surface that separates it from the **Gun Tunnel K/72**, which is described below.

Returning to Jaywick Road, the western section of the range was originally known as Range 7, and entry into this area was perhaps controlled from the standard late 1940s **Observation Post J/OP8**, sited on the north side of the road. The earliest buildings on this range lie at its western end; the **General Inert Store J7/?13** was conceived as part of the 1947 Phase I development of the site and was originally used as the **Field Photography Laboratory**. Typical of the range buildings of this date, it is brick-built and is lit by Crittall windows, with brick sills and concrete lintels, which are protected by hinged steel shutters. A sliding steel door also protects its wooden door. At a later date a small outshot was added to its northeast end, but this has subsequently been removed. Adjacent to **J7/?13** is the **Vacuum Laboratory Building J6**. It is of identical construction to **J7/?13** and probably also dates from the late 1940s. Later the building was heavily modified with the insertion of additional door openings.

On the open ground to the southwest of these buildings was Range 7, which was initially used for Civil Defence trials. Access on to this area was not possible; a plan (TNA: PRO AB16/1777) marks 'Towers' at approximately TQ 976 908. Photographs taken in 1947 show a spherical high explosive charge suspended in mid-air between two towers with a series of building models placed at ground level (Walley Collection, Envelope 3). Such tests continued in this area until at least 1953 (Figure 6, RAF 540/999 (V) 0105 2 Feb 1953).

To the southeast of these buildings is another pair of late 1940s structures, latterly used as the **Bonded Quarantine Stores J3/?36 and J4**. **J3/?36** is a two phase structure and originally comprised a rectangular building with a large observation slit and two smaller openings on its east side. Bolts on this wall indicate that it was originally protected by armour plate. Subsequently this structure was extended by the addition of a rectangular

bay to the south. Adjacent to this building is **J4**. It too probably originated as a Firing Control or Observation building as its eastern side is protected by armour plate, which is pierced by a single camera or observation aperture. Also like **J3** it too was extended by the addition of an extra bay. Both these buildings were originally constructed to control and observe a range to the east, a facility probably also associated with **J1** and **J2**. To the south of this pair of buildings is the large brick **Office and Instrumentation J5** building, which is probably also contemporary with this first phase of activity. Opposite to this building is an electrical **Sub Station SS/M**. Later additions in the area include the steel **Wernick Shelter J/SF102** at the west end of **J5**, and a prefabricated garage-like **Store J12**, which was last used by the Hydrodynamics Group. Adjacent to this is the **Septic Tank**



Figure 23: 1960s Instrumentation Building J10. (c) English Heritage DP035947

J/SF30 and close to it the **Sewage Pump House J/SF48**.

Probably during the early 1960s an additional small range was built at the angle in Jaywick Road (RAF 543/4304 (F61) 0698 14 May 1968). The most prominent structure in this group is the **Instrumentation Building J10** (Figure 23). This is a robust irregularly-shaped, reinforced concrete structure, with a heavily armoured south-facing wall pierced by two observation apertures, each with six observation ports protected by hinged metal plates. Modifications to the original structure include additional armoured plating on its south side and Pendine blocks stacked on its roof. To the south of this building is a large concrete surface 20m (65ft) × 13m (43ft). In its centre is a large grassy area, the feature is surrounded by an L-shaped traverse. At the northwest end of the traverse was an open rectangular structure, possibly a Pendine block assembly or storage area (AWE, nd). Adjacent to **J10** is a movable steel **Explosive Locker J17X** and to its north an associated reinforced concrete **Compressor House J11**.

During the last years of its operation the western end of J Range, beyond the **Observation Post J/OP8**, was occupied by the experimental hydrodynamics group. Their work included studying the effects of detonating explosives and they were equipped with a wide range of optical, electronic, radiography and electrical probe recording equipment.

K Site



Figure 24: K site from its southern and range side, to the left is the Office and Instrumentation Building K4, in the centre the Very High Speed Recording Building K3 and to the right Range Support Workshop K2. (c) English Heritage

K Site (Figures 24 and 67) is amongst one of the earliest ranges and was originally designated Ranges 8 and 9 (TNA: PRO AB16/1777). Its range offices and instrumentation buildings lie immediately adjacent to the main arterial road – Pilgrims Way. The earliest building in the area is the **Office/Messroom/Workshop K3/8**, which was constructed around 1948 as the **Very High Speed Recording Building 8** during the Phase I activities. It is brick built with a flat concrete roof and all its metal Crittall windows are protected by hinged steel shutters. At some point its southern end, facing the range, has been reconstructed in hard red bricks and is pierced by two rectangular observation embrasures. To its west is an almost identical structure **K4/34** that was probably also built during the late 1940s. In its south wall are various cable openings leading towards the test areas to the south. The third building in this area is the **Range Support Workshop K2**, which is probably slightly later in date, although it is of similar form with brick walls, concrete roof and steel shutters. K site's main firing area lay to the south of **K3/8 and K4/34** and comprised a large open concrete area with sunken cable conduits. Associated with this area are two small breeze block locker-type structures a cable **Termination Box K7** and a **Compressor House K8**.



In the angle between **K3/8** and **K2** are some minor ancillary structures, a **Pool K/SF52**, **Small Store K14** and a portable **Control Cabin K13** (Figure 25). This area has also been subject to some unofficial alterations with the creation of a small garden (Figure 26), including a breeze block wall alongside **K3** to create a flower bed, the insertion of a domestic pond liner and the planting of Cypress trees.

Figure 25: K13 Control Cabin, its aluminium body, sliding windows and mesh screens suggests it was probably a former overseas trials cabin. (c) English Heritage DP035972

To the south of **K4/35** a concrete path leads to the reinforced concrete **Instrumentation Building K5**. Running parallel with this path a sunken cable conduit connects **K4/35** to



Figure 26: K site, the remains of a small garden area created adjacent to the Very High Speed Recording building K4. (c) English Heritage

K5. On the west side of **K5** are two embrasures and some shrapnel scarring. This building may have served two small firing areas: to the southeast **Firing Point K/SF80** marked by a circular concrete hard-standing with a hexagonal steel plate at its centre, to the west **Firing Point K10** where no features are visible. This area was enclosed by an approximately square post and wire fenced enclosure, probably marking the safety

exclusion zone.

Also included within the K Range identification series are two structures **K6** and **K/SF72** which are approached from within J Range. The **Control Building K6** is of reinforced concrete construction with an armoured steel side pierced by an observation slit facing northwards towards K Range. Immediately to the north of the building is a concrete hard-standing that marks the site of **K/SF73**. To the south of **K6** is the **Gun Tunnel K/SF72**, a large structure crudely constructed from Pendine blocks, its western and southern sides partly protected by an earthwork traverse. The structure is four blocks in height and is roofed with steel sheets. A steel connecting corridor links it back to **K6**.



Figure 27: Pressure Vessel EHK, within this vessel by reducing the pressure scientists could simulate high altitude conditions. (c) English Heritage

To the east of K Site is a concrete hardstanding on which is an unnumbered semi-mobile **Vacuum Chamber EHK** (Figure 27). The large, circular, steel flask sits on a steel cradle, which is mounted on a multiple wheeled chassis. To relieve the pressure on the chassis the weight of this object it is supported at its four corners by two Pendine blocks and a substantial wooden block. It is understood that this chamber was used for the investigation of gas dynamics of payload separation during the Chevaline project (Dommett 2008, 10).

S Site Civil Defence Range and Structures Laboratory



Figure 28: The Structures Laboratory from the southwest, in the centre is S5 the Concrete Laboratory and to its right S/SF11 the Pressure Test building . (c) English Heritage

One of the attractions of the open ranges on Foulness Island was that they were sufficiently remote for large quantities of high explosives to be detonated to produce blast waves, which could be used both to mathematically model their properties and to test the robustness of different structural types. During and immediately after the Second World War considerable amounts of research was carried out to assess the effect of bombing on populations and structures, both in the United Kingdom and Europe. With the threat of attack by atomic weapons this work gained a new urgency in the late 1940s with research into the blast resistance of different types of structures. Equally the data might also be used to study the best ways in which to attack structures. To investigate these problems was a dedicated facility known initially as the Civil Defence Range, or Range 5 (TNA:PRO ESI/268; ABI6/1777) and later as the Structures Laboratory (Figures 28 and 67). The main function of this complex was the construction of scale test models, and in some instances full-size models. In addition some destructive testing was also undertaken using hydraulic presses. One example of work undertaken in this area was the design study for environmental test buildings at AWRE Orfordness. This was carried out in 1960 and involved the construction of one tenth scale models, in which small charges were exploded to simulate the effects of the accidental detonation of 400lbs (181.5 kg) of high explosives (Millington 1971).

A prefabricated concrete panel **Observation Post OPI3** located at the junction of

Pilgrims Way and Steeple Road controlled entry into the Structures Area. The area was originally unenclosed, but probably during the 1980s it was surrounded an anti-climb metal fence topped with barbed wire. There is one gate at its southwest corner and another to the north to allow access to a range area.

The priority given to the work of this section is reflected in its buildings being included in the 1947 Phase I and II programmes. By 1953 (RAF 708/82 (V) 0022 4 Feb 1953) the complex comprised three buildings, the **Structural Analysis Laboratory S4/9**, the **Concrete Preparation and Control Building S5/25** and its associated **Aggregate Store 25a**, and another building labelled **13** that may correspond with **Store S1**. This building is a **Toilet Block** to which a series of storage lockers and bays appear to have been added to the north.

Under the Phase XI building scheme of 1955, proposed construction is listed for the **Structure Laboratory S4/9** and the **Concrete Laboratory S5/25**. This work mainly involved extensions to existing buildings. An air photograph taken in November 1955 reveals that the small **Store S6** had also been added (RAF 58/1920 (V) 0084 5 Nov 1955). In keeping with the general delays associated with many of the building programmes, the south eastern extension to **S5**, and the work to double the size of **S4**, does not appear to have been begun until 1957 (RAF 58/2322 (V) 0323 3 Dec 1957).



Figure 29: Office, Casting Workshop and Laboratory S5, press by A Macklow Smith Ltd, London and a Beacham high pressure oil pump. These were used for stress testing various materials. (c) English Heritage BB99/15969

S4 was extended to the south and its role was as an **Office, Workshop and Electrical Laboratory**. At the northern end of **S4** is a small, probably brick-built **Chemical Store S8**.

The earliest section of the **Concrete Laboratory S5** is at the northwest end of the complex and comprises a single storey brick building, constructed from a reinforced concrete frame and clad in bricks laid to stretcher bond. Its metal Crittall windows are protected by steel shutters against the effects of stray debris thrown from tests. It is entered through double sliding doors on its north-eastern elevation, which led into a large workshop area. This in turn gives access to an office, battery room, and a test room with a press for the destructive testing of samples (Figure 29). The extension of this building, although planned in 1955 does not appear to have started until 1957, but was completed by 1962 (RAF 58/5377 (V) 0055 9 Aug 1962). To the southeast of the original building a single storey office building was constructed and linking the original structure to a tall brick assembly or test building. This is entered through double sliding doors on its north side; its roof is supported on steel RSJs, which also support a lifting gantry. Internally, is a gallery along the rear and north-west wall. Viewing slots in latter wall, and high pressure lines in the room to the rear, may suggest that experiments using high pressure gas bursts to simulate blast waves were carried out in this building. During the 1960s the **Pressure Test Building S/SF11**, a tall steel-framed building with corrugated iron cladding, was added to the south eastern end of this complex (HSLE Essex, frame 0387, 16 Sep-1970). The area is served by two **Septic Tanks S/SF32** and **S/SF37**, which lie to the south of **S5** and northwest of **S4** respectively.

To the northeast N Range was considerably expanded during the 1970s and was probably in part undertaking work for other organisations. Both to maintain the confidentiality of work in the **Structures Laboratory** and to accommodate the increased traffic into the area a diversionary road was built around the south of it, which allowed vehicles for N Range to avoid this area. It was probably also around this time that a prefabricated **Observation Post S/OPI1** was erected to the north of the area to monitor access into N Range from the Navestock Road. A decade or so later the **Structures Laboratory** was surrounded by the anti-climb fence. To the north the fence cut across the old N Range access road, forcing all traffic for N Range to pass around the south of the area. Also at this time a number of new structures were built in the area. To the north of **S5** these included the steel sheet clad **Storage S13** building and adjacent to it another steel sheet clad building, the **Pressure Test Building S/SF22**. A **Propane Gas Storage Tank S/SF55** to the southeast of **S/SF11** probably also dates from this period. The tank has been removed and a concrete slab marks its position.

To support the work of the structures team there were two dedicated ranges. The earlier Range 5 lies to the north of workshops and is centred on the **Trials Control Building S7 (37)**. This comprises a demolished rectangular concrete blockhouse and to its north a protective trapezoidal concrete wall and to its north a concrete test surface 10m (33ft) × 4.5m (15ft). To its south is a movable Steel Field Building S12, which was used to house monitoring instruments. Further to the north was an unidentified feature **S/SF78**; there are a number of concrete surfaces in this area that may equate with this feature. It is thought that the 'Water Lily' trials, involving the barium chloride were held

in this area during 1960-1961 (Carl Bro 2006, 26).

To the southeast of the main group of buildings was another range or trials area, known as Range 5A, which is now approached from two gravel tracks off the Navestock Road. This range originally comprised a single dirt track leading to a cross-shaped feature, probably surrounded by a circular fence (RAF 58/1920 (V) 0084 5 Nov 1955). This is now covered by an irregular earthen mound, either dumped as convenient tipping place or to contain what lies beneath. Probably during the 1970s (HSLE Essex 0387 16 Sep 1970) this area was remodelled and the main feature was centred on a long rectangular concrete surface of unknown function **S/SF76**, orientated southeast to northwest and 88m (288ft) in length. At its centre is a concrete slab 7.3m (24ft) x 6.3m (21ft) with various cut-off steel sections that probably indicate the position of a building and test rig. On the long surface to either side of the slab are further cut-off bolts, which may have been used to fix cable conduits or other sections of test rigs. At the northwest end of the feature is a filled concrete bund 5.5m (18ft) x 4.02m (13ft) standing to a height of 0.9m (3ft), which may represent a fire pool. To the north of the linear feature is another concrete surface of unknown use **S/SF56** and a movable **Instrumentation Van (PF Rig) S/SF58**. To its northwest is a small brick **Electric Sub-Station S3**.

N Range

N Range is a large area to the northeast of the **Structures Laboratory** and occupies about a quarter of the total AWE range area (Figures 30, 68 and 69). It covers much of the land formerly farmed by New Marsh Farm to the northeast, and was sometimes referred to as the New Marsh Range (Davidson 2006, 11). This range was the latest to be developed and most of the infrastructure was constructed in two main phases, during 1954 and sometime around the mid 1970s. Access into area was originally through the **Structures Laboratory**, but probably during the mid 1970s a loop road was built to the south to permit direct access. The earliest range feature in this area was a fenced circular feature with a small circular mound at its centre (TQ 9864 9156) (58/1008, V, 4, frame 0016, Feb 1953), which lies to the northwest of the later **Office and Workshop NI2**. The circular feature was known as the 'Bullring' and is thought to be location of the 1956 Series B 'Ra La' trials. It is believed that these may have used polonium and depleted uranium (Davidson 2006, 11).

Due to the expansion of the **Explosives Storage Area** and the **Headquarters Area** more remote firing areas were required. This probably accounts for the first major expansion into N area, which took place during the 1954 Phase VII development scheme and which was complete by November 1955 (RAF 58/1920 (V) 0084 5 Nov 55). Prior to this date the surfaced road had terminated in a hammer head to the northeast of the **Structures Laboratory**, from here it was extended northeastwards to two new ranges. These were sited to either side of the crossroads adjacent to the **Recording Laboratories NI/58** and **N2/59**, Range 10 to the west and Range 11 to the east. Both **Recording Laboratories** are of brick construction, with metal Crittall windows with concrete lintels and sills, and all are protected by hinged steel shutters. To the east of **NI** is the **Septic Tank N/SF33**. In its last phase **NI** was used for **Offices, Stores and Laboratories** and **N2** as a **Mess Room**. To its rear is an unidentified feature **N30**, which is represented by two parallel



Figure 30: N Range in 1973, cutting diagonally across the photograph from top to bottom is Foulness Road and leading off to the bottom left is Pilgrims Way with the Structures Laboratory to the left. N area occupied most of the land to the north of Pilgrims Way, the crossroads at its centre are clearly visible and adjacent to them the circular 'Bullring'. MAL 49/73 0019 09 Sep 1973 (c) English Heritage NMR

concrete slabs 15m (49ft) x 2m (6ft 6ins). During their latest phase these buildings were associated with the **Cable Terminal Building N18**, a metal framed **Store N21**, and an unknown, and now demolished structure **N20X**. To their northeast is the **Sub Station SSJ** and adjacent to it a **Mobile Trials Cabin N33**. On the opposite side of the track was **N29**. No trace of this feature was found suggesting it was a movable facility.

Sometime after 1973 (Figure 30, MAL 49/73 0019 09 Sep 1973) there was a major expansion of N Range. This probably reflected a diversification of the range's activities, including the investigation of unqualified explosives and proof testing service munitions. During this phase an Explosive Sensitivity Facility was developed on Range 10 for testing the sensitivity to impact of new service explosives. It included a number of features including the **Spigot Intrusion Test Facility N-SF19** (Figure 31) It comprises an angled crane-like steel gantry arm secured by steel wires, from which explosives were raised up to 44m (144ft) and dropped onto a steel target plate. Grouped around this feature are a number of associated structures. Close to the entrance to the area is a reinforced concrete and brick **Workshop N3**. In its west elevation are three small square recesses with circular armoured glass observation or camera ports, on its north side are four



Figure 31: Spigot Intrusion Test Facility N/SF19. BB99/15977 (c) English Heritage

similar apertures. These features suggest that in origin this building was either an observation or control building. On the opposite side of the track is a contemporary reinforced **Recording Room N6**. On the access track to the east of **Workshop N3** is a crude **Fort Lift Truck Garage N23** created from Pendine blocks and on the opposite side of the track a **Magazine N/26X** of similar construction. Beneath the **Spigot Intrusion Test Facility** are a number of small buildings, including a small open concrete **Store N/20**. To its north was **N22X**. This was not found, its suffix suggests that it was a movable steel explosives locker. Many of the buildings in the area are constructed from Pendine blocks including a **Protected Work Area N22**, **Explosives Lockers N27X and N28X**, and the **Cable Terminal Building N16**. To the west is a tall steel portal **Lifting Frame N/SF47** with Pendine blocks at its base to create a blast screen.

Also during the 1970s to the southeast of the crossroads a large octagonal reinforced concrete **Hazard Assessment Facility N14** (Figure 32) was constructed surrounded by a low post and wire fence. It is entered through steel doors to the southeast and northwest and internally is a steel-lined octagonal firing chamber, which is open opposite to the door openings. The structure is capable of resisting blast and fragments from the equivalent of 3.6kg (8lbs) TNT. Reactions might be initiated by detonators, or by firing small bore projectiles into a test object. Within its compound are a Pendine block **Explosive Lockers** numbered **N19X** and **N25**. **Explosives Locker N24X** has been removed. To the southeast of this facility, on Navestock Road, are a prefabricated **Nitrobenzine Store N/SF99** and a prefabricated **Observation Post N/OP9**.



Figure 32: 1970s Fragmentation Control Building N14. (c) English Heritage BB99/15975

Beyond the crossroads the new road was extended northeastwards towards the existing circular feature and a spur road was laid to its centre. This feature appeared to have remained in use until the early 1960s, but by 1968 the fence and the features at its centre had been removed (RAF 543/4304 (F62) 0698 14 May 1968). Probably during the mid to late 1950s a small group of buildings was added at the entrance to the spur road, a brick **Office and Workshop N12** and brick built **Store N5**. Ancillary features associated with these buildings included a **Septic Tank N/SF21**. **N21X** was not found, but again its suffix suggests that it was a movable explosives locker. Likewise numbers **N/SF84** and **N/SF85** to the northwest and southwest of N12, many also have been allocated to movable objects.

As part of the mid-1970s building programme the road to the northwards of the **Office and Workshop N12** was extended for a further 565m (1853ft). The most substantial building in the new area is a small reinforced concrete **Recording Room N10**. To its north are two prefabricated **Stores N31** and **N32**. Two other features **N/SF104** and **N25X** lay close to the Stores, neither of these were found. At the end of the track was another small unidentified building **NEH1**; this has been demolished, a scar on the slab reveals the building measured 1.85 (6ft) x 1.87m (6ft). To its northwest, and close to the perimeter fence, is a late 1940s **Observation Post N/OP5**.

Also during the mid 1970s (MAL 49/73 0019 9 Sep 1973) the road to the east of the crossroads to Range II was extended eastwards to a new **Office and Instrumentation N11** building. About half way along this track is a T-junction to a short southward leading spur track. At its junction is the site of **N/SF86**. This is represented by a rectangular concrete surface 7.65m (25ft) x 7.55m (24ft 9ins). It has a grassy centre and four projecting arms with cable channels. To its east is a **Cable Terminal Building**



Figure 33: FV432 armoured personnel carrier that was used as a mobile protected shelter. (c) English Heritage

N9, a simple small concrete structure with double doors and a steel plate roof. On the opposite side of the road is a small breeze block **Store N8**.

The new **Office and Instrumentation N11** building is a single storey brick structure with windows protected by hinged steel shutters. To its rear is a **Septic Tank N/SF44**. On the opposite side of the track and to its south is a concrete block **NEH3** that perhaps supported a mast. Associated with this structure is a steel shipping container **Store N23X**, a prefabricated garage-style **Pyrotechnics Store N/SF97**, and **N/SF75** a steel instrumentation **Cabin**, which has been moved to F Range. To the southeast of this group of structures was **N/SF95**. Its site was inaccessible but roughly corresponds with an area used in the 1990s for air blast and fragmentation trials, using temporary steel scaffold poles structures.

From the **Office and Instrumentation N11** building the track was extended north eastwards for about 150m (490ft) where it then turned a dog leg north eastwards. At the end of the track the most significant building is the brick **Winch House N13**. To its northwest are a large circular open concrete surface and an unidentified feature **N/SF61**. In the area are a number of scattered Pendine blocks that may represent its remains. Closeby is an abandoned armoured personnel carrier (Figure 33) that was used as a mobile protected range instrumentation shelter. To the southeast of **N13** is the site of **N/SF60**. This is marked by a rectangular concrete slab 5.55m (18ft) x 5.65m (18ft 6ins) and a smaller concrete slab with a fixing bolt. In the area there are also three fixings for guy ropes or wires. A sign reads 'Instructions before operating maximum load 80kg maximum suspension height 27m centrally position'. These features, along with **Winch House N13**,

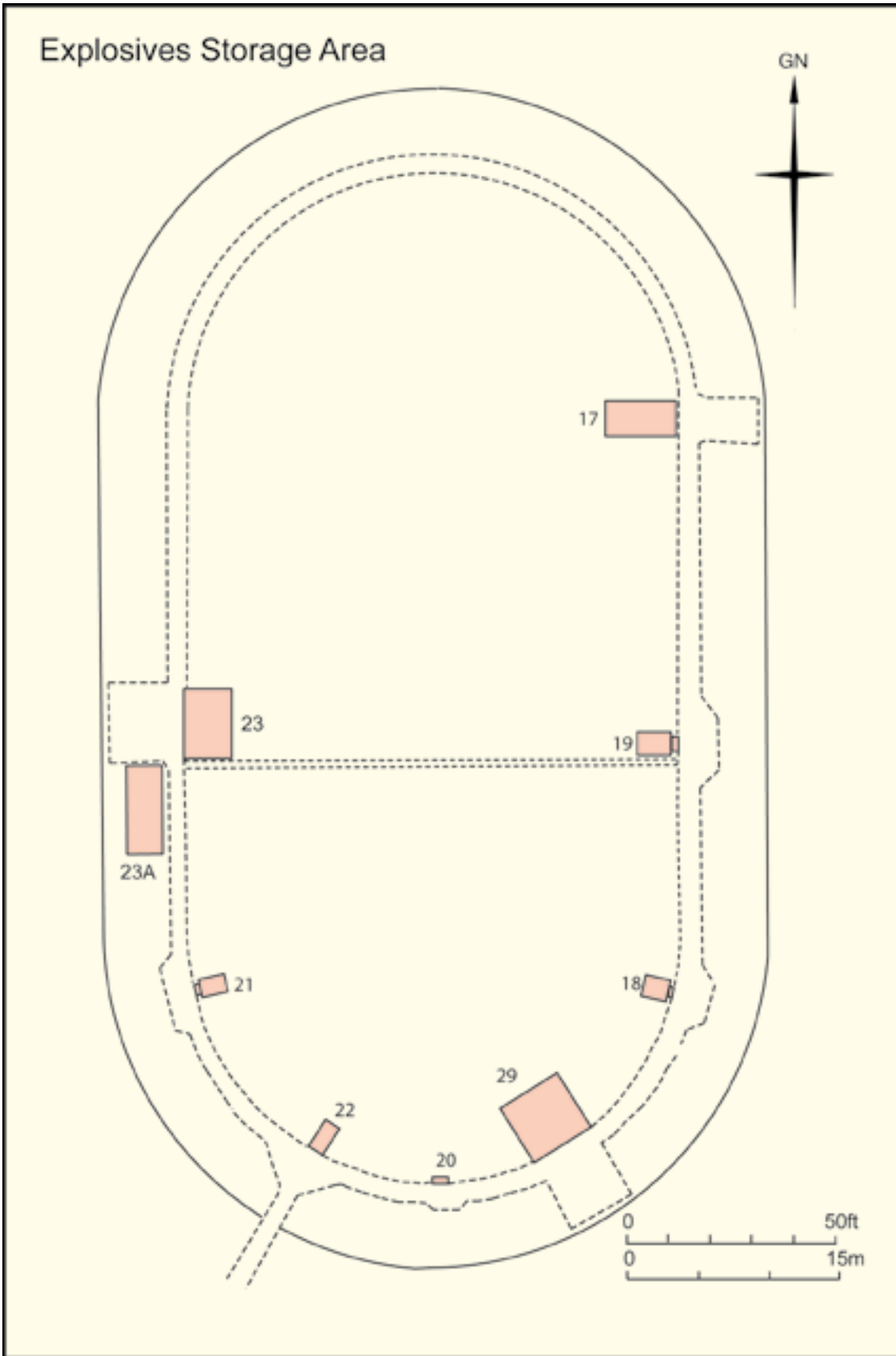


Figure34: Explosives Area, 19 December 1947, after TNA: PRO ESI/330

suggest that a gantry used for air burst explosive trials occupied this area. To the east of this area is a late 1940s **Observation Post N/OP6**.

The Explosives Area

The Explosives Area (Figures 34 and 70) lies towards the northern end of the AWE area, between the site of **Smallgains Farm X26** and Smallgains Point on the River Roach. The area is entered along Oxney Road, a short spur road leading off north from the main arterial road, Pilgrim's Way. At the junction access into the area could be monitored from a prefabricated **Observation Post OPI0**. After crossing a drain Oxney Road splits into three. One arm heads directly for the main gate of the explosives area, to the east another arm heads for a small self-contained compound, with **X30** at its centre, and to the west the third arm originally passed to the south of **Smallgains Farm X26** before heading due north to the River Roach. The site of Smallgains Farm X26 is marked by the slightly higher area of ground, covered by the **Offices XI** and their car park to the west. The built-up ground raises the possibility that archaeological deposits may survive in this area.

The 1940s

The initial design of the Explosives Storage Area was prepared to serve the new Armament Research Department range, but its layout was quickly altered to meet the needs of the High Explosives Research project. The operations of this area were similar to those in an explosives filling factory, whereby explosives and other components manufactured elsewhere were brought together for assembly. The original layout was an elliptical enclosure, with its central axis oriented north to south, following the alignment of the pre-existing drains in the area (Figure 34). The area was formerly covered by wide drainage ridges, which were levelled prior to construction work. Within the enclosure was an elliptical concrete access road that followed the line of the fence with a single entrance at its south-west corner. This served the explosive storage and handling buildings, most of which were arranged on the inside of the track. It is unclear if the proposed elliptical fence was erected, for by 1953 the area was enclosed by a rectangular fence with projections at its four corners and midway on its long sides to allow the exterior of the fence to be monitored by police patrols (RAF 540/1026 (V) 0178 6 Feb 53). To the north of the area set against the back of an earthwork dyke is a standard late 1940s brick **Observation Post X/OP4**.

In late 1947, a number of last minute modifications were made to the original plan to serve the needs of the new establishment. On 29 December, Roy Pilgrim, Superintendent of the Foulness range, and a veteran of the Bikini Atoll nuclear tests, wrote in a memo (TNA: PRO ESI/330).

Recent modifications to the programme of work to be undertaken on the range make it necessary to ask for some additions to the list submitted in June.

The most significant alterations to the original plan were the modifications and enlargement to the **Explosives Preparation Laboratory X6/23** (Figure 36) and the



Figure 35: Special Store 22, now Magazine X3, was built in 1947, typical of this date is its brick construction and copper clad doors. Characteristic of explosives buildings are the lightning conductors, copper earth straps and external electrical fittings. DP035923 (C) English Heritage

addition of the **Non Explosives Components Stores X5/23A** and the **Explosives Casting and Pressing Laboratories X23/29**. Also included in the initial layout were the **Special Store X3/22** (Figure 35), **Fuze and Flash Store X4/21**, **Powder Store X23A/18**, **Bulk HE and Bare Charge Store X21/19** and the **Bomb and Shell Store X20/17**. All these structures were constructed under building phases I-VII, which were initiated in 1947 and 1948, despite its high national priority construction work often proceeded at slow pace (TNA: PRO ES 1/330). Also at this time, to control the entrance, a **Police Lodge XPP2** was built and opposite to it a small building that was probably originally a **Search Room X25**. It was also during the late 1940s that the **Water Tank XWT6** was constructed. Another feature present by this time was an unidentified building **X18** that stood to the north **X7**. This building had a tower at its eastern end (V, 540/1026, frame 0178, 6 Feb 53) and it is unclear if it pre-dated the Explosives Storage Area, but it appears to be similar in form to a number of towers on Foulness Road observed on air photographs. It is believed that the tower was demolished during the 1980s and all that remains of this building is a concrete floor slab.

During the late 1940s two main activities were carried out in the Explosives Storage Area. Centred on the **Explosives Preparation Laboratory X6/23** (Figure 5) experience was being acquired in the assembly of the high explosive lenses that surrounded the atomic bomb's fissile core. In other buildings specially shaped high explosives charges were being manufactured for use on the ranges. The term 'laboratory' for a room where loose explosives were handled and assembled into munitions has a long lineage and may be

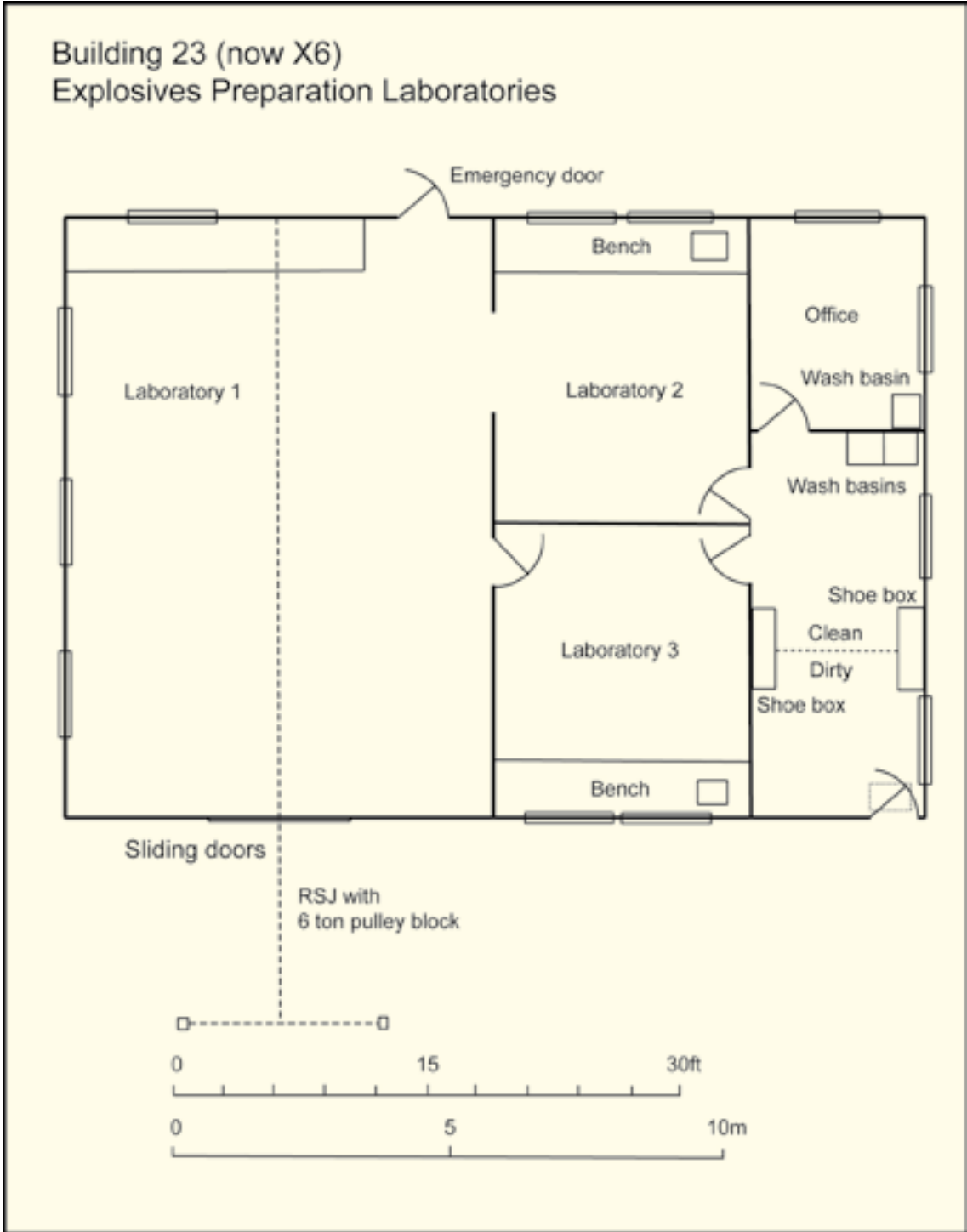


Figure 36: Explosives Preparation Laboratories X6, was 23, drawing as specified 18 December 1947, after TNA:PRO ESI/330

traced back to at least the early 19th century Board of Ordnance establishments.

In late 1947 modifications to the original plans meant the specifications for the size of the **Explosives Preparation Laboratory X6/23** were altered and its size was quadrupled from 7600 cu ft (215 cu m) to 34,974 cu ft (990 cu m) (Figure 36). This implies that, at a relatively early stage in the project, Foulness was identified as the place of assembly for Britain's

first atomic bomb. The design and modifications made to **X6/23** are also consistent with the intention to build an atomic device of comparable size to the *Fat Man* bomb that was dropped on Nagasaki in August 1945. The width of the main door opening, and the RSJ with a 6 ton pulley block, indicates that they were working on the assumption that the device would be comparable to the *Fat Man* physics package. Personnel entered the



Figure 37: Building X6 was 23, Explosives Preparation Laboratories, interior of Laboratory I showing the main entrance door and over head lifting beam. (c) English Heritage AA99/09785

building through a single copper-clad door at its southern end. This led into a changing area typical of any building associated with handling explosives. On entering is a 'dirty area' where outdoor shoes were placed in the shoe boxes and if necessary, clothing changed. The personnel then stepped over the toe board, separating the dirty from the 'clean area' and put on the regulation magazine shoes. At the eastern end of this room were wash basins and an office, and to the north were doors into **Laboratories 1 and 2**. The relatively wide central door opening measuring 6ft (1.83m) between the main assembly room, Laboratory 1, and Laboratory 2 may suggest that some assembly work was done in this room. Laboratory 3 was used in later years as the Metrology Room, and there is a large and heavy steel table at its centre. This was used for the precise measuring of components prior to assembly. It is known that Mr Hessen (Cathcart 1994, 182) was in charge of the metrology in 1952 and it is presumed that Laboratory 3 had this function at that date.

Once construction was complete the **Explosives Preparation Laboratory X6/23** played an important role in the development of the explosive lenses. Technically the manufacture of the lenses was extremely challenging, each of the lenses comprised alternate layers of cast high and low explosives. These had to be produced to very fine tolerances and free from any internal cracking that might develop during cooling. The explosive element of each lens was held in an outer aluminium shell, these were then joined together to form the bomb. The precision of this assembly work was absolutely critical to the operation of the bomb, as any misalignment of the lenses might result in the misdirection of the explosive shock wave on the fissile core. The basic principles were known from the wartime Manhattan Project. It was, however, an entirely new process to the British team tasked with the production of lenses. To approve this novel design and to gain experience work at first concentrated on assembling a few lenses for test firing on the ranges. Later, in the lead up to the *Hurricane* test, assembly work was practiced on an inert device, *Alfred*. These preparations culminated in the summer of 1952 in the assembly of up to three atomic devices for the *Hurricane* test that resulted in the successful detonation of Britain's first atomic device. Assuming that three devices were assembled in **X6/23**, it is inconceivable that they would all be held in the one building. This raises the question of where the additional devices were stored prior to dispatch. The only other contemporary building of sufficient size is the **Bomb and Shell Store X20/17**. Its overhead lifting beam and formerly open interior appear to be of sufficient size to have handled and accommodated at least two devices.

The **Explosives Preparation Laboratory X6/23** survives substantially unaltered since the late 1940s; the principal changes have been the removal of the external RSJ lifting beam and a reduction of the door opening to Laboratory 1 (Figure 37). Hinge brackets adjacent to the windows indicate that lockable steel shutters formerly protected them.

Opposite to **X6/23** is the **Non Explosives Components Store X5/23A**, its function is self-explanatory and supported the activities in **X6/23**. When the lenses for the bomb were delivered from Woolwich they might either be taken directly to the **Explosives Preparation Laboratory X6/23** or held in store. Buildings that may have been used to store the lenses include the **Bare HE and Charge Store X21/19**; a contemporary footpath leading directly to **X6/23** may also suggest a functional relationship between these buildings. Building **X3/22** (Figure 35) described as a 'Store for munitions which may not be stored in other explosives stores' and was also referred to as a **Special Store**



Figure 38 Explosives Preparation, Casting and Pressing X23, was 29, to the rear is the raised roof of the room that housed the 200 ton press. (c) English Heritage DP035935

(TNA: PRO ES 1/267), may also have been used for this function.

In addition to work on the development of the bomb another priority during the late 1940s was the understanding of blast effect on buildings to assist in civil defence planning. During the Second World War considerable knowledge on the effects of blast had been built up (Walley 2001, 15-17) by studying bomb damage on different British building types and, immediately after the war, by visits to Germany and Japan. By 1947, some consideration was being given by the Fort Halstead team to the use of balls of high explosives to simulate the effects of an atomic air burst (TNA: PRO WO 195/9368). To support this work specially shaped charges of high explosives were required to simulate the blast waves produced by larger explosions, the results of which could be mathematically scaled up to model the effect of an atomic weapon. It was probably to support this work that the **Explosives Casting and Pressing Laboratories X23/29** (Figures 38 and 39) were also specified in late 1947. This building is entered from the south through double copper-clad doors into a lobby area, which also gives access to the Motor and Boiler House. Personnel entering the building were required to change into magazine shoes and clothing before passing over a barrier into the 'clean area'. Explosives, presumably in sealed containers, were also brought into the building through the main doors suspended from the L-shaped RSJ lifting beam, rated at 1 ton. Once in the Explosive Preparation Room they were presumably unpacked before being taken to the Casting Room or one of the press rooms. Along the northern side of the building are three press rooms and a Compressor Room, where the hydraulic pressure for the adjacent rooms was produced. Due to the hazardous nature of the activities

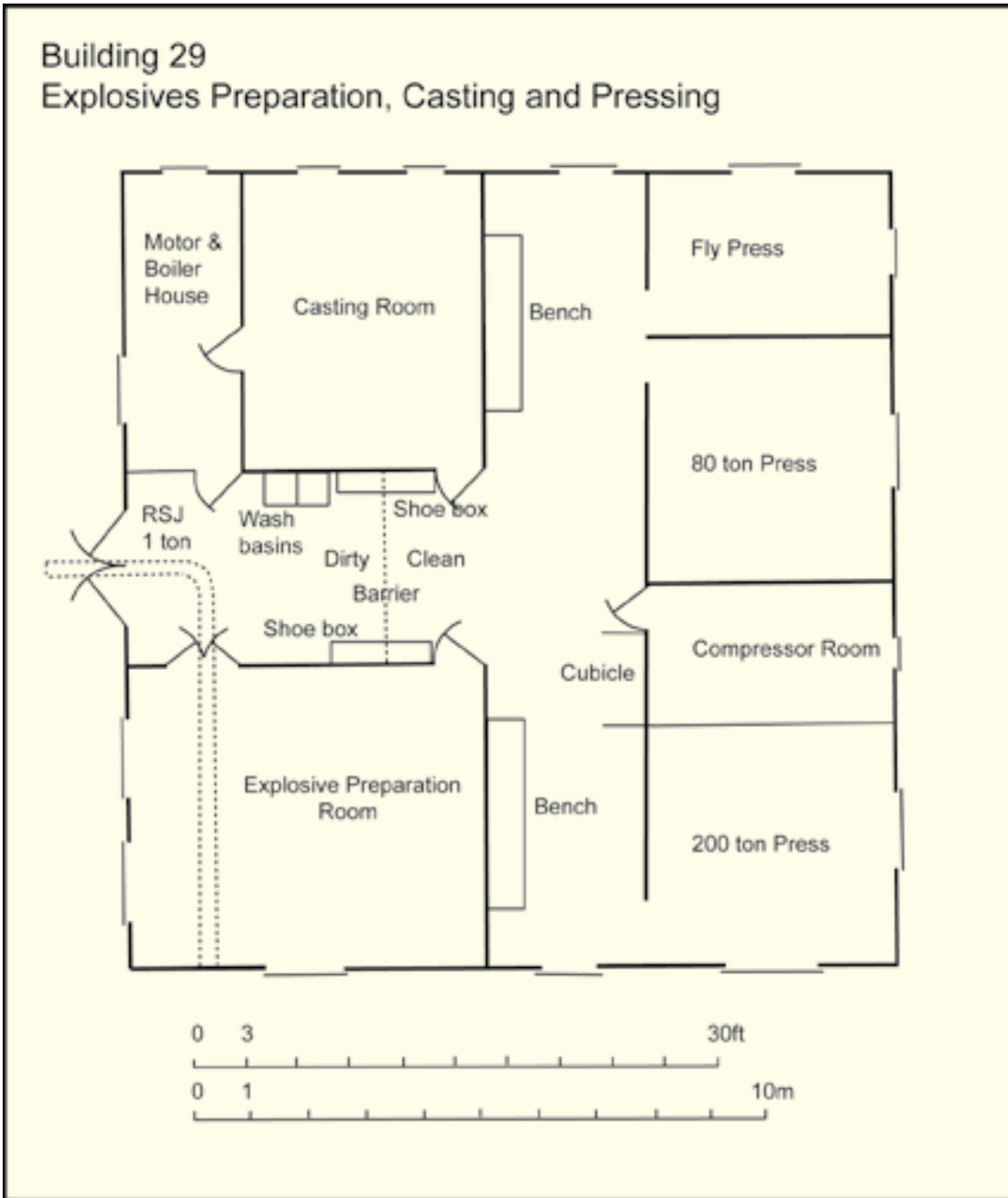


Figure 39 Explosives Preparation, Casting and Pressing X23, was 29, as specified in December 1947 after TNA:PRO ES1/330.

the main spine wall separating the press rooms from the central corridor is formed of 14 inch (0.36m) thick reinforced concrete. The fly press and 200 ton press specified in December 1947 remain in place, along with a compressor and 1 ton lifting beam. At a later date, to improve the building's operational safety a number of doors were inserted in its outer walls. An early modification to the building appears to be a set of tall, copper-clad doors giving access to the 200 ton press room and linking it directly by a cleanway to the **Powder Store X23A/I8**. A cleanway was also constructed around the western and northern sides of the buildings, and three doors inserted into its west wall. On the northern side a door was inserted to give access to the compressor room and

the internal access to this room blocked.

As described above the 200 ton press room was directly linked by a cleanway to the **Powder Store 23A/18**. Adjacent to the press room, and accessed from the cleanway, is the **Compressor House 23B**. This building was not shown on the original 1947 design drawing, but was in place by 1953 (RAF 540/1026 (V) 0178 6 Feb 53). To the north of these buildings were the **Bulk HE and Bare Charge Store X21/19** and the **Bomb and Shell Store X20/20**. To the west of **X23** were other small stores, the **Detonator Store X24**, **Special Store X3/22** and **Magazine X4/21**.

The explosives related buildings in the area are protected by lightning conductors. Depending on the size of the building they either use a single or double pair of poles, with a wire strung between them. This method of protecting explosives buildings became the recommended arrangement in the late 1940s and was used from the outset at Foulness.

The 1950s



Figure 40: Casting Shop X10, was 56, built about 1953, with a rear reinforced concrete wall and to the right is later breeze block and earthwork traverse. (c) English Heritage DP035931

The start of the next major building campaign may be confidently dated to early 1953, by a series of air photographs that were taken during the disastrous floods of February 1953,



Figure 41: Casting Shop X10, was 56, showing the steam heated jacketed mixing bowls used to melt and cast high explosives. (c) English Heritage BB99/15981

which show the foundation trenches of a number of buildings (RAF 540/1026, V, frame 0178, 6 Feb 53). This building campaign may be equated to Phase VI, originally planned in 1951-2. To the east of the gate the foundations of the **Mess Room X29** had been dug. The most significant additions at this date were in the northwest quadrant of the area, including three explosives processing buildings **X9/55**, **X10/56** (Figure 40) and **X11/57** and a **Shifting Room X7/54**. This section is entered through the **Shifting Room X7/54**, where workers arriving from the dirty area to the south were able to change into special explosives area boots and clothes before proceeding northwards on the cleanway laid on the outer side of the oval access road. Immediately to the north of **X7/54** was the pre-existing building **X18**, it is not known if this building was incorporated into the new section. Moving northwards the original functions of the buildings were the **Machining Building X9/55**, **Casting Building X10/56** (Figure 40) and the **Machining Building X11/57**. The three process buildings are of a standard form, with an L-shaped plan, a reinforced concrete rear wall and a reinforced concrete roof, projecting to the north and east. The remaining walls are constructed from a Fletton-type brick, they are lit by metal Crittall windows with well-formed concrete sills. Internally they are divided into a main work room and two rear rooms. The **Casting Shop X10/56** differs slightly from the other two structures with a tall tower to the rear, perhaps for a water tank, and four vents above the casting machines (Figures 40 and 41). Air photographs taken in February 1953 show a couple of small buildings on the inside of the main track, these had gone by 1955 and probably represented builders' huts (RAF 58/1920 (V) 0055 5 Nov 55). Also by 1953

work had begun on the construction of a building on the site of **Magazine M4**.

To hold the increasing amounts of explosives being handled by the section two **Magazines M2** and **M3** had been built to the south of **M4** by November 1955 (RAF 58/1920 (V) 0055 5 Nov 55). **M4** is identified as a **Magazine Locker**, but it is uncertain if this building had this number in 1955, or if the present building was standing in 1955. To serve the new magazine group the main access from the south was relaid, which



Figure 42: Explosives Machining shop X13 built about 1955, this group of buildings were distinguished by well-finished brickwork, gravel washed lintels and sills, and teak doors. To either side are later breeze block and earthwork traverses. (c) English Heritage DP035934

probably required the demolition of a building immediately to the south of **Smallgains Farm X26**. A small breeze block **Chemical Locker X33** was also added in the northeast quadrant. Other additions at this date include the **Store X21A** that may be equated with the **Process Laboratory 19A** built in Phase VII (1954). Also around this time, to the northwest of the explosive area, a tall mast **EH10** was constructed; this appears to be unconnected with explosives handling. To the east of the explosives area a track was laid to a detached explosives machining area, centred on the building **X30**.

Construction work continued throughout the 1950s, and in summer 1956 foundations were prepared for a row of four small buildings immediately to the north, the Phase XI **Press Houses X12, X13** (Figure 42) and **X14** and the **Magazine X32**. In form the Press Houses are similar to the earlier process buildings **X9-X11**, later they were converted to other functions. They are L-shaped with a main work room and two rear rooms. They are well-finished buildings with reinforced concrete rear walls with a washed gravel finish. The other walls are constructed from yellow stock bricks; the window openings have washed gravel lintels and concrete sills, metal Crittall windows and teak doors were used

throughout.

By July 1956 the foundations of the **Chemical Laboratory X2** had been dug (RAF 58/2011, V, frame 0061, 27 Jul 56). This was associated with the detached **Chemical Store X19**. In the 1960s, or possibly the 1970s, this building was converted to a depleted uranium and beryllium machining facility (Davidson 2006, 12). The vents on its roof probably indicate the position of machines below. The hazardous nature of the operations in this building is marked by a post and wire fence, which surrounds the two buildings. Other changes during the late 1950s included the demolition of **Smallgains Farm X26** and the construction of the **Offices XI** on its site. An additional **Magazine MI** was also constructed to the south of **M2** and at the northern end of the magazine area an **Explosive Locker M6** was built. In its northern wall are eight metal lockers, which were used to store small amounts of explosives. A road was also constructed to the east of **X20** to a pair of new buildings **Explosives Inspection XI6** and a small concrete building **XI6A** that probably originally functioned as a plant room for **XI6** (RAF 58/5377 (F21) 0055 9 Aug 62).

To dispose of any waste materials, including small amounts of explosives a **Burning Ground EH9** was established close to the River Roach, its northern and western sides enclosed by an earthwork bank. This was the site of the large explosion on 1 October 1957. Adjacent to the Burning Ground a large crack appeared in the **Lookout Shelter X/OP4**, and the range of facing buildings **XI2**, **XI3** and **XI4** were damaged.

The 1960s and beyond

During the late 1960s the major modification to the area was the creation of protective breeze block and earth traverses for the six explosives processing buildings **X9-X14**.

On the island any form of ballast or material for creating traverses, or blast mounds, has always been at a premium. To gather enough gravel for the traverses a large sub-rectangular pond was dug in the centre of the elliptical service road (RAF 543/4304 (F62) 0698 14 May 68). In the centre of the pond an island was left for the benefit of nesting wildfowl.

The **Cottages** to the west of **Smallgains Farm X26** may have been used as police accommodation and remained standing until at least the early 1970s (MAL 49/73 0021 9 Sep 1973), but were probably demolished later in the decade. During the 1970s or 1980s the magazine area to the west was extended with the addition of four more **Magazines M7-M10** (Figure 43) **Magazine M10** was fairly short-lived and it was destroyed during the 1980s after an explosion caused by an electrical fire. Ten 8-shaped holes drilled in opposing traverse walls mark the position of for horizontal steel poles to support the structure to allow the investigators to inspect its ruins. During this period another **Explosives Casting** building X34 was built to the east of **XII**, protected by a concrete traverse that appears to have used Pendine blocks for shuttering. Minor structures added at this time include, close to the main gate the steel-framed **Garage X45** and to its north a prefabricated **Garage Store X22**.

During the 1980s climatic explosives testing was moved from the Royal Arsenal,



Figure 43: M9 Magazine, showing the typical protective L-shaped wall and inner brick magazine found in this area. (c) English Heritage

Woolwich to Foulness. To support this work four almost identical **Climatic Test Buildings X35-38** were built to the east with additional roads. The buildings are steel-framed with lower sections clad in brick and their upper sections and roofs clad in pressed steel sheeting, and they are all surrounded by earthwork traverses. Also associated with this work was the **Explosives Inspection building X16**, which was re-roofed and the adjacent building **X16** modified for use as a **Chemical Store X16A**. Also in this area two prefabricated garages were built to accommodate a **Compressor House X17** and a **Water Softening Plant X46**. At the northern end of this area an x-ray facility was added to investigate the presence of any internal cracking in the explosive charges. This comprised the **X-Ray Facility X40**, a steel-framed and steel sheet clad building shielded on all sides by a concrete traverse and an L-shaped Pendine block wall to the north. The buildings are surrounded by a post and wire fence, an illuminated light warned personnel when the x-ray machinery was in operation and entry to the area was controlled by a lifting barrier. Operations in the **X-Ray Facility** were controlled from the detached reinforced concrete **X-Ray Control Room X39**. Also associated with these buildings is the **Climatic Store X31**, another prefabricated garage building. To the rear of X6 and X21, **Plant Rooms X6PR** and **X21PR** were added. Both are now represented by empty concrete floor slabs and probably held freestanding transformers. The three Explosives Machining buildings **X12-X14** were also modified to improve their safe operation. To the east of the buildings small reinforced concrete control rooms were constructed, shielded from the explosives buildings by concrete panel, breeze block and earth traverses. To the rear of the buildings a steel-framed corridor clad in translucent corrugated fibreglass panels joined the control rooms to the machining buildings. From the control rooms the operators were able to remotely direct the machining aided by

close-circuit television. To further enhance the environmental controls within **X12** the door and window openings in its north side were walled up. To the rear it was also provided with a new detached brick **Plant Room X12PR**.

To the east of the main explosives area is a self-contained compound containing a small building complex. It comprises a tall free standing two-bay reinforced concrete wall, which houses two north facing **Explosives Machining** buildings **X42** and **X43**. To their north is **Dust Extractor X44**. Operations in these buildings were latterly controlled from the **Control Room X30**, a brick built structure to the south of concrete traverse wall. These buildings have subsequently been linked to the west by a steel-framed corridor clad in translucent fibre-glass panels. It was perhaps at the same time that another freestanding reinforced concrete **Explosives Machining** building **X41** was added to the west.

Headquarters Area

The Headquarters Area (Figure 71) lies at the far northwest extremity of the range at the end of Pilgrims Way, just over 2 km (1 1/3 miles) from the main gate. On the south side of Pilgrim's Way between the Headquarters Area and the Explosives Area is a single, prefabricated concrete panel **Observation Post OPI**. The Headquarters Area comprises around 70 buildings most of which were built before 1962 and fulfilled a number of functions. They provided a variety of services for the range, including administrative services, welfare and canteen facilities, workshops, laboratory and office accommodation, facilities for small scale experimental work, and vehicle maintenance. The area is roughly rectangular in shape, slight misalignments of its roads and accretions of structures to its sides are indicative of a complex that has grown organically, rather than being conceived at a single point in time.

Between 1947 and 1952 there were seven documented development phases (see Section 11). Unfortunately, no contemporary map is available and it has not been possible to correlate all the building numbers from these phases to the latest numbering scheme. Documented building delays suggests that there was often a considerable hold-up between planning and execution, and in reality construction work was probably running concurrently on a number of identified schemes. It is convenient to ascribe the first seven identified building phases to a single construction period. An air photograph (Figure 44) taken after the great flood of February 1953 provides an opportune snapshot of the extent of this area during the period after the development of the first British atomic bomb (RAF 708/82 (V) 0190 4 Feb 1953).



Figure 44: The Headquarters Area photographed during the February 1953 flood. (c) Crown Copyright RAF 82/708 v 4 Feb 1953 0190



Figure 45: 1949 Armaments Research Establishment headquarters A2, was 10. (c) English Heritage BB99/15966

By this date an irregular shaped fence surrounded the Headquarters Area. The main entrance from Pilgrim's Way was at its east end. Entry into the area was controlled from a small **Police Post H11**, latterly used as a **Store**. This is a small brick building, with a porch to its north; opening in its side walls allowed a guard to monitor movement in the area. Opposite to this is a small brick building **Messengers and Cleaners A9**. Its original

function was probably as a **Search Room**. Today there is a single door to the east and a corresponding blocked door to the west. Adjacent to this was a **Sub-Station H10**. Above its blocked door a painted over sign appears to read 'Sub Station G', the 'G' being unclear. This building was also later converted to a **Store**. To its north is another small brick building latterly occupied by the **Messengers and Cleaners A8**. Its form suggests it was a self-contained office, perhaps for the police.



Figure 46: Canteen A7, was 24, is typical of buildings of this date with brick walls, a flat concrete roof, metal Crittall windows with concrete lintels and sloping brick sills. (c) English Heritage

Beyond the **Police Post H11** the access road split into three, to the south it headed for the **Administration Offices A2 (10)** (Figure 45) to the north towards the **Canteen A7/24** (Figure 46) and to the west to a large concrete hardstanding in front of the **Garage A10/16**. These buildings, along with the **Photographic A4/11** buildings formed part of the 1947 Phase I building programme. However, a plaque above the main door to the **Administration Offices A2/10** (Figure 45) records 'A.R.E. 1949', which confirms Penney's complaint about the delayed building programme. The plaque also both acknowledges the controlling department, the Armament Research Department, and maintains the subterfuge of the establishment's real purpose. The building is well-constructed to a purpose-built design; it is probably supported on an internal reinforced concrete frame, which is clad in bricks laid to stretcher bond and has a flat concrete roof. The main entrance to the building is through a pair of double doors on its northern elevation; on its west end is a projecting porch, with double doors, a large window above providing light to the internal staircase. The building is lit by Crittall-type steel framed windows, with brick lintels and sloping brick sills.

Internally, the building retains its original layout, with a central corridor on both floors giving access to the offices and other rooms. To further increase the security of papers and drawings that might be held in this building, in March 1948 it was suggested that the

rooms of the scientist-in-charge and his assistant should be protected with steel shutters. It was also recommended that their ground floor rooms should be separated from the rest of the building by a steel lattice gate (TNA: PRO ESI/330). It was also requested that a telephone with a 'scrambler' should be installed in the office of the scientist-in-charge for communication with Fort Halstead. It was in this building that William Penney worked when he visited Foulness. More detailed analysis of the building is required to determine if these features were installed, and whether any traces still survive.

To its west was the **Photographic A4/II** building, which included processing and projection facilities. This was a standard rectangular brick building with a flat concrete roof and Crittall windows. The original building lies to the east and was subsequently enlarged westwards. It is presumed that the **Main Stores A10** represents the original **Garage A10/16** building. Its east elevation was originally open and has subsequently been infilled and is now entered through two smaller double door openings. It also appears that a gabled roof, which has been replaced by the current flat roof, originally covered the building. Also associated with this building were two now demolished features. Immediately to its north was a Vehicle Inspection Ramp 16b. The position of the **Fuel Store 16a** is un-located, although it may be equated with a small structure shown between the **Vehicle Inspection Ramp** and the **Water Tank Q/WTI** (RAF 708/82 (V) 0190 4 Feb 1953). To the east of **Garage A10** and on the site the **Administration Offices A6**, was a large gabled building; a track leading to its east side suggests that it was a garage or store. It was demolished in around 1956 to make way for the **Administration Offices A6**.



Figure 47: Late 1940s office buildings, to the left H2, was 40, and to the right H3, was 49. (c) English Heritage

Using the known building numbers from the phase list (see Section 11) it appears that the range of buildings oriented roughly southwest to northeast, **H1** to **E11**, were

conceived of in 1949. Buildings **H1**, **H2**, and **H3** (Figure 47) were last used as **Offices**, a function that they have probably retained since their construction. They are all of a similar brick construction with flat roofs and Crittall windows with concrete lintels and brick sills. To their north was the **Main Carpenters Shop E11** which is formed from two separate buildings, to the south a gabled **Store 41** and to the north a flat roofed building **47**. These were later joined together by a single bay with a north-light window. As discussed above the **Photographic A4** building was extended westwards and was latterly used as **Offices** and a **Computer Centre**. A peculiar feature of this building is a central tower with a self-contained upper room entered from a staircase on its south side, windows in this room face south and westwards. Also built at this time was the **Telephone Exchange A3** that lies between **A2/10** and **A4/11**.

By 1953, the Headquarters Area comprised about 18 buildings arranged in a roughly rectangular shape and surrounded by a fence that narrowed towards the main gate located at the east side of the enclosure. Outside of the compound to the northeast of the main gate were two, probably timber-framed, gabled huts which were approached from a track close to the main gate. These were subsequently demolished.

Mid 1950s developments

The next significant expansion of the Headquarters Area occurred from 1954 onwards and coincides with the government's decision to proceed with the development of the H-bomb. The mid to late 1950s was a time of intense activity for the Atomic Weapons Research Establishment. The main priority was the development of the thermonuclear hydrogen or H-bomb. In addition, it was also working on a smaller tactical atomic bomb, in service use known as Red Beard and other devices, such as *Pixie*, a proposed warhead for use with surface to air missiles that was later abandoned. The construction work at this date may be equated with building Phases VII-XVI. During this period the extent of the administrative area was tripled and its security fence was pushed outwards and extended to the north to link with the establishment's outer fence (RAF 58/2011 (V) 27 Jul 56 0084) (Figure 48). Also around this time the original rudimentary and inefficient road network was replaced by a roughly sub-rectangular perimeter road that enclosed most of the buildings and linked the new structures to the HQ area's new main gate.

Air photographs show that between 1953 and 1956 a number of buildings were added to the western end of the original administration area, unfortunately it has not been possible to correlate these with any of the documented building phases. To the north of the **Main Carpenters Workshop E11/41 & 47** a new **Carpenters Mill E10** was added, a concrete framed structure with an asbestos sheet roof. To its rear a brick **Timber Store E14/68** was also built, and later extended southwards. On the open ground on the opposite side of the road to the **Carpenters Mill** two stores, **H4** and **H5**, were added. These have subsequently been demolished, but scars on their floor slabs reveal that they were reinforced concrete framed structures, each 15 bays in length. Anecdotal evidence suggests that they were used as cable stores, both for use on the range and for overseas trials (pers. comm. R Crump). To their northwest and on the opposite sides of the crossroads a **Fire Station H6** was built, a steel-framed structure with breeze block walls. To its rear a **SubStation SS/K** was also added. The most substantial building



Figure 48: The Headquarters Area in July 1956 showing the post 1954 expansion to the west, east and north. (c) Crown copyright 58/2011 v 27 Jul 1956 0084

constructed in this area at this date was the **Laboratory and Offices H9** building. This is a large brick building with a central corridor with office accommodation to either side. A feature peculiar of this building is the presence of two self-contained laboratory rooms at the west end of the building. To its rear is a steel Braithwaite **Tank Q/SFI** with pipework connecting back to **H9**.

In 1955, the Phase X building campaign marked a considerable westward expansion of the original administration area, comprising a large group of offices, workshops and laboratories. The urgency of the work at this time is reflected by the use of a contemporary prefabricated lightweight building system, which may be seen as a model of their type (Mills 1951, 60-65) (Figures 49 and 50). This system combined economy of materials with speed of erection, while presenting a contemporary industrial design. The main elements of the system were made up from an internal frame formed from square, steel, hollow section members. The roofs are supported on lightweight flat steel lattice trusses; internally the roofs were insulated with compressed wood straw panels. Externally the buildings were faced in standardised washed cement panels, although on the upper sections of the workshops pressed stainless aluminium panels were also used. They were glazed by standard steel framed Crittall type windows. The pedestrian doors to the buildings were wooden with concrete or pressed metal canopies supported



Figure 49: Main Mechanical Workshop E2, this building exhibits many features typical of the mid-1950s structures, including the hung concrete wall panels, Crittall windows, pressed aluminium sheet cladding and a porch canopy supported by a tubular steel framework. (c) English Heritage DP035959



Figure 50: Main Mechanical Workshop E2, northern bay showing its steel framework construction and roof trusses formed from steel sections with tubular steel struts. (c) English Heritage DP035920

on tubular steel columns, while the larger openings to the workshops and stores were originally entered through large sliding doors. Internally, they were either lined in brick or had a cement rendered surface and were often painted pale blue.

At the northern end of the group is the double storey **Offices E1** (Figure 51) and to its south the large **Main Mechanical Workshop E2** (Figures 49 and 50) that was last used



Figure 51: Prefabricated Offices E1 built about 1955. (c) English Heritage DP035960

as the AVE Manufacturing Centre MME Facility. Internally, it is divided into three large bays providing large flexible working areas, each entered from the west through large double sliding doors and lit by roof lights. The two end bays, to the north and south, have overhead travelling cranes supported by a freestanding steel framework. Along its northern side is a single storey annexe that was mainly used for office accommodation; to the south is a similar annexe housed a number of light engineering machine bays and a compressor house. A number of machines remain in this building. To the east the main building is connected by a corridor to the **Plant Room E2/PRI**- a single storey cement rendered building. On its east wall is a further **Annex Plant Room E2/PR2**. This may be a later addition, though the cement rendering has obscured any visible relationship. To the south of **E2** is the **Central Stores E3**. This comprises a taller area to the west and a lower section to the east. The taller section is divided into three bays, each of which is lit by a roof light and are entered through three tall doors to the west. A brick wall divides this part from the lower section, which is entered through double doors on its northern and southern sides. Along its east side is a row of offices.

To its south a block of five standard, single storey buildings were constructed, each 121ft (36.9m) x 37ft 8ins (11.48m) (Figure 52). Entrances through double wooden doors protected by porches were variously placed on the ends or sides of the buildings, similarly their interiors were arranged to serve their particular needs. The buildings



Figure 52: Prefabricated Laboratory L1 constructed about 1955 and to the right the slightly later brick built Electronics Laboratory L6. (c) English Heritage DP035967

were **Laboratories L1 and L2**, **Engineering Design Offices L3**, **Laboratory L4** and **Photographic Section L5** and, at the centre of the group, a brick **Boiler House E15**, which was later extended to the east. An air photograph confirms that all these prefabricated buildings and the **Boiler House** were completed by November 1955 (RAF 58/1920 (V) 0084, 5 Nov 55). To the northeast of the **Boiler House E15** is an associated brick **Fuel Bund Q/SFI00** that formerly surrounded a 50,000 litre oil storage tank. This was probably constructed sometime during the 1970s, and may represent the changeover from solid to liquid fuel. Probably during the 1960s a breeze block **Compressor House L7** was added to the rear of **Laboratory L3**. This was probably associated with luminising work in **L3**, whereby items for radiography were electroplated under vacuum with gold or silver (Davidson 2006, 8). Another, smaller and perhaps later **Compressor House L8** was sited at the eastern end of **L4**. This has been removed and its site is marked by a concrete surface 2.7m (8ft 9ins) x 2.15m (7ft).

Reflecting the increasing intensity of activity as part of the 1954 Phase VII developments, it was planned to move the motor transport section from the centre of the expanding administration area to the northeast corner of the Headquarters Area. This section was responsible for the establishment's vehicle fleet, including coaches, cranes, commercial vehicles and trailers. To the east of the original entrance a large concrete hardstanding was laid. On its west side a brick **Motor Transport Office T1/60** and the large, three bay **Motor Transport Workshops T2/61** were built. It was probably also at this time that the underground **Fuel tanks T6** and **T8** were installed to the east of the hardstanding. Associated with these tanks are a small brick **Petrol Kiosk T7/63**, **Switch Room T8** and an **Oil Store T9/62**, although the present building may be a replacement of the 1950s structure. To make way for these developments two unidentified huts to the northeast of the compound were probably demolished around this time. The perimeter fence was also moved eastwards to enclose the new development.



Figure 53: Shock Tube Laboratory H8, was 72. (c) English Heritage

To support the enlarged establishment a number of additions were made around 1954 to its infrastructure. To the north a new **Sewage Filter Bed Q/SF7** was constructed and to its south a **Sewage Pump House Q/SF5**. On the southern side of the site a similar



Figure 54: Shock Tube Laboratory H8, was 72, interior. (c) English Heritage DP035979

Sewage Pump House Q/SF8 was built serving the **Sewage Filter Bed Q/SF9**. Also built in this area around this time was a brick structure that was last used as a **General Stores Compressor E17**. Its form, however, suggests it may have originated as a **Sub-Station**.

To the north of the Headquarters Area in late 1955 or early 1956 work began on the **Experimental Building H7** and the **Shock Tube Laboratory H8/72** (Figure 53). The **Experimental Building H7** is brick built and comprises a tall chamber to the west, surrounded on three sides by an access corridor. There is another raised chamber to the north and to the south a small office section. At the north-west corner of the building is small detached structure surrounded by a brick wall. Unfortunately, the original number of this building is unknown. Its form, date and close association with other structures in the area, suggests it might be equated with the Phase VIII **Firing Chamber 71**. To the east and on the opposite side of the road is the **Shock Tube Laboratory H8**, which may also be part of the Phase VIII developments and can probably be equated with the **Large Stock (sic Shock) Tube 72**. It is a two phase L-shaped building of brick construction and originally comprised a single range oriented southeast to northwest, with offices at its western end. By 1962, a second arm, oriented southwest to northeast was constructed (RAF 58/5377 (F21) 0056, 9 Aug 62). The earlier shock tube was mounted on 0.77m (2ft 6ins) gauge rails and the later one on mainline standard gauge rails 1.42m (4ft 8½ ins). At the southern end the later cut the line of the earlier rails, this indicates that its shock tube was removed when the larger one came into service. The later shock tube (Figure 54) remains in the building and is 44m (145ft) in length and projects 2.73m (9ft) beyond the building's north wall. It is made up from a series of rectangular steel sections strengthened by external ribbing, which measure in section 0.76m (30ins) x 0.46m (18ins). Towards the north end of the building are projections to the east and west that allowed test items to be inserted into a movable section of the tunnel. In the last years of the range's operation two shock tubes were in operation, the large one described above and a smaller one. It is not know where this tube was located. It measured 6m (8ft) in length with a cross-section of 0.203m (20ins) by 0.051m (2ins).

The physical replication of nuclear weapons effects was a major component of the work at Foulness, which required many specialised pieces of equipment. To model the blast wave produced by a nuclear explosion one method was to explode a charge of conventional high explosive and mathematically extrapolate the results of larger detonation. To carry out this work in a more controlled environment shock tubes were also used to study weapons effects and to develop instrumentation equipment, as well as other scientific uses. A shock tube comprises a long steel pipe, of either circular or rectangular cross-section, which is divided into two by a diaphragm. The air behind the diaphragm in the compression chamber, usually the shorter end of the tube is pressurised, the diaphragm is then burst to develop a shock wave in the large expansion chamber. A shock tube for Civil Defence research was amongst the first items of equipment to be installed in Building 11/3a during the 1947 Phase I development. The 206m (675ft) Blast Tunnel I/SF6, where the blast wave was propagated by a length of explosive mining cord, is an extreme version of a shock tube. This dwarfed by an example in the United States where a 600m (1970ft) long tunnel was constructed. A similar device for studying pressure waves is known as a 'leaky chamber'. This comprises a large and small pressure chamber. A typical size might be 2½ cu ft (0.07075 cu m) for

the large pressure chamber and 0.056 cu ft (0.0015848 cu m) for the smaller expansion chamber, which also has a small diameter hole or 'leak' in its casing. As with a shock tube the two chambers are separated by a diaphragm, which is burst to produce a pressure wave. Neither, shock tubes or leaky chambers produce a long duration blast wave as found in a nuclear explosion and in the early 1950s a piece of movable apparatus, known as the atomic blast simulator was devised (SZ/BUF/3/1 Wright 1954). This may probably be equated with structure **70** listed under the Phase IX 1955 development programme; it no longer survives (see Section 11). This was perhaps originally sited on Range I close to building 3A, now 11.

To the south of **H7** is a small brick **Calorifier E16**, which was associated with the central steam heating network. Adjacent to **H8** is a similar **Calorifer E23**. They were probably built during Phase VIII, documentation of which refers to **Calor Chambers 74** and **75**. To the rear of **H8** is an unidentified **Tank Q/SFI05**.

Documentary sources indicate that in 1955 a Phase XII development plan was agreed to construct new larger **Administration Offices A6** and an enlarged **Canteen and Common Room A1** (Figure 55). Air photographs reveal that construction work did not start until the following summer (RAF 58/2011 (V) 0084 27 July 1956). At this time it appears that the ground was being cleared for the **Canteen and Common Room A1** and the building that stood on the site of the **Administration Offices A6** was being dismantled. The walls of the **Surgery A5**, a Phase XVI structure, had been completed but it was still roofless. Opposite to the **Surgery**, work had also begun on the **Waste Chemical Store E13**. This



Figure 55: Boiler House E4. (c) English Heritage

is a windowless, rectangular brick building with two single doors on its west side, and possibly an inserted double door on its east side. It is protected by copper earthing straps and lightning conductors and, along with external electrical fittings and red painted fire switches, suggests it may have originated as an explosives **Magazine**. Equally the storage of volatile chemicals may also have required these precautions.

The enlargement of the Headquarters Area and also the increase in manufacturing and research activities placed greater demands on the infrastructure of this area. At the time that the prefabricated workshops and laboratories were added, a brick **Boiler House and Demineralisation Plant E9** was built between **E2** and **E3**. This complex also included the **Sub-Station SSL** and three transformer bays, each of which housed an 11,000kv transformer. As part of the 1955 Phase X activities a new **Boiler House E4** (Figure 55) was planned, although construction didn't take place until after July 1956 (RAF 58/2011 (V) 0084 27 July 1956). This is a very robust concrete framed building infilled with brick, it is divided into four bays that are accessed from the south through four roller shutter doors. Above each of the bays, except the western one is a tall stainless steel chimney. To its west is a small single storey annexe that was used as an office. The **Boiler House** was oil fired and to its east is a two phase brick **Fuel Bund E18**. Soon after its construction to the rear of the **Boiler House** a breeze block **Boiler House Emergency Generator E12**



Figure 56: Canteen and Common Room A1, built in 1956. (C) English Heritage DP035913

building was added and adjacent to it a concrete **Fuel Bund E25**. Most of the buildings in the Headquarters Area were heated by a district steam heating system, represented by the network of lagged steam pipes.

The new **Canteen and Common Room A1** (Figure 56) was placed at the south corner of the administrative area and was the first building visitors saw when approaching the area. Internally, it is divided into 10 bays by 6 bays. Its large size reflects the significant growth in the establishment's workforce, which had grown to over 400 by March 1955. In addition 35 members of the Armaments Research Establishment, 14 canteen staff



Figure 57: Canteen and Common Room A1, interior showing the main dining room with the bar to the rear. (C) English Heritage DP035914

and a small detachment of War Department police also worked on the range (TNA: PRO ABI6/916). It is a light and airy building constructed from a reinforced concrete frame in contemporary 1950s style, with large glazed elevations on all sides except to the north where there is a lower aisle housing the kitchen. The large glazed elevations give views across the marshland and to the south the large grassy area between it and the perimeter fence was often used for impromptu lunchtime football matches. Although it is utilitarian in appearance, it is a well-finished building with supporting chamfered concrete columns, dwarf brick walls below the windows and brick end walls. At eaves height the tops of the windows have been finished in corrugated hardboard. Its architecture also clearly illustrates the rigid civil service hierarchies of the 1950s. The main entrance for most of the workforce is on the eastern side where three of the bays are inset to create a porch area with two pairs of doors to the rear. The remainder of the bays on this elevation are glazed with metal-framed windows with dwarf brick walls beneath. On the southern, and longest, elevation the two end bays at either end are filled with brick walls laid to stretcher bond, the remaining central bays are glazed. The entire western elevation is glazed. The building has a flat concrete roof and to allow light into the centre of the room (and probably to help to dissipate cooking smells) there is a central clerestory and raised roof lights. Internally, there is a large open dining room floored in a chequer board pattern of blue and white tiles and lit by pendant lights with large white glass shades (Figure 57). To the north was a servery area and to the west a carpeted bar area separated from the dining room by a partition decorated with copper panels decorated with embossed abstract designs. On the west wall was a large world map. The separate entrance for the senior staff was close to the **Administrative Buildings A2 and A6** double doors gave access to small lobby area with toilets and then into smaller dining area with wooden parquet flooring.



Figure 58: Administration Offices A6 built about 1955. (c) English Heritage

To the north is the **Administration Offices A6** a double storey brick building with a flat concrete roof, which as described above, sits on the site of an earlier building (Figure 58). The main entrance to the building is through an entrance porch set into a rebated corner at its south end. This is opposite to the western entrance to the earlier **Administration Offices A2** and probably reflects the close working relationship of the two buildings. To the rear of the building are two short projecting wings; the upper floor of the northern one was probably occupied by the superintendent of the establishment. This is distinguished by a balcony accessed from Crittall French windows and protected with decorative iron work. The main entrance on this side of the building was through a set of double doors protected by a cantilever canopy. This gave access to a staircase executed in a restrained 1950s style and lit by windows the full height of the building. During survey work it was not possible to enter the building, but it is known that at its southern end there was a lecture theatre and elsewhere in the building there is a strong room for sensitive documents.

Also during late 1955, or early 1956, to accommodate the establishment's growing vehicle fleet, a large concrete parking area was laid to the north of the motor transport section.

Late 1950s

To keep pace with the demands being placed on the establishment during the late 1950s, both to contribute to the refinement of warhead designs and trials associated with the development of the civil nuclear programme, construction work continued into the early 1960s. To the north of the motor transport section's hardstanding, a large metal framed and asbestos sheeting clad **Coach Garage T4** (Figure 59) was built. The main section was entered through three large sliding doors, later replaced with roller doors,



Figure 59: Coach Garage T4 built in the late 1950s. (c) English Heritage

and to the east was a lower annexe also originally entered through a sliding door. Also around this time two brick **Fuel Bunds Q/SF67** and **Q/SF68** were built on the opposite side of the hardstanding. These comprise rectangular brick walls, each of which formerly contained a 4,500 litre diesel tank.

At the eastern entrance to the area the **Cover Control Q/PP3** building was constructed. This is a double storey brick building; on its east side, facing the approach road and the ranges, is a large window at ground floor level and an upper projecting window. At ground level on its longest sides, to north and south, were single doors although the one to the south has subsequently been blocked. Given its position this building may have once acted as a **Police Lodge** controlling access to the Headquarters Area.

Stylistically, a group of buildings built at the western end of the area reverted back to more traditional brick forms. To the north the **Electronics Laboratory L6**, was added to the group of five prefabricated laboratories erected as part of the Phase XVI 1956 development scheme. It is a large rectangular building with a main entrance at the centre of its northern side and double doors at the centres of its east and west sides. Further buildings constructed around this time were also brick built, including, on the opposite side of the road, the **Works Services Department E5**. To its north, and rear, a long concrete framed with brick infill **Stores and Workshop E7** was added. By 1962 the **Maintenance Workshop E6** had also been added. This is identical in design to **E5** and is supported on a steel frame with outer brick cavity walls. Its gently sloping roof is supported on lightweight lattice trusses (RAF 58/5377 0056 9 Aug 62).

To the west of the **Main Mechanical Workshop E2** and the **Central Stores E3** were added a number of ancillary structures, including to the south a **Stores Compound E21**, and to its north a **Fuel Bund E24** for the adjacent **Emergency Generator E8**. To its north is a steel-framed and asbestos sheet clad **Metal Stores E26**.

The 1960s and beyond

After almost 15 years of sustained building programmes there was little new building activity after 1962. As discussed above, this may be related to a number of factors, including the renewed nuclear co-operation between the United States and the United Kingdom, the consolidation of the country's nuclear warheads on a handful of standardised designs, and the poor state of the economy and the need to scale back from expensive defence research programmes.

As a consequence the buildings erected during the late 1950s were the last significant additions to the Headquarters Areas, and the only alterations made during the 1960s were extensions to some of the hardstandings (MAL 49/73 0021 9 Sep 1973). During the 1970s, in common with other areas, a number of prefabricated garages were built mainly for use as stores. At the western end of the site these included the **Waste Asbestos Store E34**, **Materials Store E30** and **Paint Store E31**. Three concrete floor slabs in this area probably also represent the remains of demolished prefabricated buildings, **Road Sign Store E32** and three unidentified buildings **E28**, **E35** and **Q/SF 101**. The steel framed **Scaffold Store E33** and the **Glasshouse EH6** were also built around this time. In the centre of the area a steel-framed **Waste Oil Store E22** was built to the rear of **E2** and a prefabricated store **EH7** to the rear of the **Boiler House E4**. Also in this area a breeze block **Gas Bottle Store E20** was built immediately to the north of the **Main Stores E3**. Around this time additions were also made to the motor transport section at the eastern end of the administration area. At the southern end of the **Motor Transport Workshops T2** a prefabricated **Ambulance Garage Q/SF 93** was built, and to the north of **T2** similar prefabricated buildings, a **Store T3** and the **Boat and Tyre Store T11**. Other minor additions to this area were the steel framed **Oil Store T9** and the **Observation Post T10**.

In the 1960s a number of buildings at the northern end of the Headquarters Area were probably involved in civil reactor safety experiments. Building **E17** was probably converted to this new role, while the steel framed **Compressor House E29** was added around this time. To the rear of **E17** was an unidentified and now demolished structure, **E19**. It is understood that one of these structures contained a sodium rig, and there may also have been uranium oxide wash down facilities in the area (Davidson 2006, 8).

Mobile cabins also provided extra accommodation, a **Mess Room E36** to the rear of **E11**, and close to the **Laboratories** two **Portakabins L9** and **L10**.

6 DISCUSSION

This discussion section is split into two main sections, the first provides a brief historical summary of the physical development of the range's landscape and the second discusses the forms of the range's structures.

Pre-military activity

Physically underlying the post-war remains of the Atomic Weapons Research Establishment (AWRE) is a complex archaeological record of previous land use. This is represented by buried Romano-British remains and earthwork remains of medieval sea defences and tracks. Traces of post-medieval farms, cottages, and cultivation practices also survive as earthworks and buried archaeological deposits; in some instances excavated evidence indicates that some may have medieval origins. The area is also cut by a dense pattern of irregular ditches and drains, most unaltered since the Second World War, which adds to the distinctive character of Foulness Island.

The Second World War

Prior to the Second World War the range's danger zone extended to a north to south line to the east of Smallgains farm. During the war air photographs indicate extensive military activity in the area later occupied by AWRE. This is represented by the construction of curved asbestos huts probably for use as stores buildings. Many were concentrated around the existing farm complexes, but some were also scattered across the range area. Scarring on the grassland visible on historic air photographs may mark the positions of experimental detonations by the Armaments Research Department (ARD) to study the fragmentation patterns of various types of munitions. Traces of this wartime activity may be revealed by very slight earthworks and, in the pasture areas, fragments of bomb and shell casings may remain. Also to the south of the later Explosives Area historic air photographs record the position of an anti-aircraft battery. The form of the site suggesting it might be a 1944 Diver site, created to counter the threat from V1 flying bombs.

The atomic bomb era

After the war the ARD planned to consolidate its activities on Foulness Island. It was at this time that the initial planning for the Headquarters Area, the Explosives Storage Area, and some of the ranges took place; these plans probably correspond with building Phases I-IV (see section 11). In June 1947, the primary function of the new range was altered from the investigation of conventional explosives to support the development of Britain's atomic bomb. This top secret work operated under the cover of High Explosives Research, an autonomous section of ARD, which became the Armaments Research Establishment (ARE) in 1948.

The buildings associated with the early development phases reflect the establishment's two main primary research areas – the development of the Mark I nuclear weapon and the investigation of blast effects for Civil Defence purposes. Closely associated with

the development of the warhead were the significant late modifications made to the layout of the Explosives Storage Area. These included the redesign of the **Explosives Preparation Laboratory X6/23** so that it was large enough to assemble an implosion device similar to the wartime *Fat Man* bomb. Also added to the original specification was the **Explosives Casting and Pressing Laboratories X23/29**, designed to produce the specially shaped high explosive charges required by the range for the Civil Defence trials. On the ranges, especially Range I, were areas where large amounts of high explosives could be detonated. Such sites were required to test the composite high explosive lenses that surrounded the fissile core of the weapon; when assembled the Mark I warhead contained about 2.5 tons (2.54 tonnes) of explosives. Detonation work was also important to test and calibrate the instruments that would be used in the atomic tests and to train the scientists in their use. From the surviving documentary evidence it is not possible to tell if any major alterations were made to original requirements for the Headquarters Area, although special security measures were discussed for the **Headquarters Block A2**.

During the early 1950s developments at Foulness reflect the wish to concentrate atomic weapons work within establishments directly under AWRE control. Within the Explosives Storage Area, buildings for explosives casting and machining were erected. These developments coincided with the appointment of an explosives expert from the Royal Arsenal, Ernest Mott, as the range Superintendent. This may indicate that the development of the explosive lenses used in various warheads was moved to Foulness at this time. In 1955, an unspecified research group was moved from Fort Halstead to Foulness, the majority of the nuclear weapons team having already been moved to Aldermaston.

Cold War Civil Defence

In addition to the work carried out on nuclear weapons, the investigation of the effects of such weapons was also of utmost importance. Not only did it contribute to the development of the country's civil defence strategy, it also provided significant data that could be exchanged with the United States. The 1946 United States Atomic Energy Act (McMahon Act) had effectively closed off discussion about nuclear technology between the United States and United Kingdom. The passing of the 1954 Atomic Energy Act eased these restrictions in many areas where Foulness staff had particular expertise, including the effects of nuclear weapons on personnel, equipment and structures. Through experience acquired both at Foulness and overseas trials, Foulness staff had acquired knowledge that was of interest to the United States. In tandem with the high level political discussions to restore full nuclear co-operation between the two countries, briefings by AWRE staff reinforced the credibility of British scientists in this field. Nuclear co-operation between the United States and United Kingdom was made possible by the 1958 United States Atomic Energy Act and the subsequent Agreement for Co-operation on the uses of Atomic Energy for Mutual Defence Purposes (Hennessy 2007, 124).

The thermonuclear era

The development of the 'Super' or hydrogen bomb may have been anticipated by some

of the establishment's leading scientists since the end of the war, however, it was not until 1954 that the government decided to proceed with such a project. During the following years the size of the Headquarters Area was almost tripled, including the construction of six large prefabricated **Laboratories LI-6**. The increase in staff also called for an increase in support buildings, including a new **Canteen and Common Room AI**, along with improvements to the site's infrastructure. The mid 1950s was period of intensive activity for the establishment. In addition to the development of the hydrogen bomb, the establishment was also working on the smaller fission weapons and the proof testing of plant associated with Britain's civil nuclear programme.

From the mid-1950s activities in Range I appeared to have altered, perhaps coinciding with the completion of work on the Mark I *Hurricane* type devices, used in the RAF's first nuclear weapon *Blue Danube*. Weapons of this type used large amounts of high explosives to initiate the nuclear reaction, the testing of which is represented by large areas of scarring visible on air photographs. Later nuclear weapons used far smaller amounts of conventional explosives and Range I was partly remodelled.

The 1960s and beyond

After the intense activity of the 1950s the character of the range's activities underwent a marked change of emphasis. The 1958 *Mutual Defence Agreement* gave the United Kingdom access to information on United States warhead designs. Rather than devising new warhead designs the stress was on Anglicising American designs to ensure the compatibility of materials and devices produced to British standards, and to guarantee that the weapons met British safety and operational standards. The late 1950s had also seen a growth in requirements from the armed services for small tactical warheads, but by the end of the decade both their utility and cost were being questioned and as the British economy worsened most were eventually cancelled. By the late 1960s the United Kingdom had standardised the number of warheads in its stockpile to a relatively small number of types. Some such as the warheads for the WE177 series, remained in service for a number of decades.

The 1963 Partial Test Ban Treaty also changed the emphasis of the investigations at Foulness. The Treaty prohibited the atmospheric testing of nuclear weapons. Underground testing remained permissible but such trials were both costly and required access to facilities on the United States Nevada Test Site. While some questions could only be resolved by live tests, weapons effects may also be studied by individually modelling the four main effects of a nuclear detonation: blast and shock waves, light and heat radiation, initial nuclear radiation, and electromagnetic radiation. The personnel at Foulness were particularly skilled in modelling blast effects and shock physics. Their capabilities in this field were greatly increased by the construction of the **Air Blast Simulator I/SF6**. It is the only example of a tunnel of this scale in the United Kingdom, and it is believed that the only other examples in Europe are in France, one in a disused railway tunnel while the other is a purpose-built structure. Heat radiation was investigated in the **Thermal Radiation Facility J/SF20**, where very high temperatures could be simulated by burning liquid oxygen and aluminium powder.

While work proceeded on the development for the WE177 series of weapons, in late 1962, after the abandonment of the American *Skybolt* programme, there was an urgent requirement to produce the ET317 warhead for the submarine-launched Polaris missiles (Hennessy 2007, 148-54). This work appears to have been accommodated in the existing buildings and there is little evidence for new building work during the 1960s. Subsequently, AWRE was involved programmes to upgrade the *Polaris* warheads that would ultimately result in the *Chevaline* warhead and its replacement the *Trident D5* warhead. In the foreseeable future it is unlikely that any technical details will be released on the work carried out to support the *Polaris* upgrade programme *Chevaline* and the current *Trident D5* warheads. Nevertheless, all are known to be very sophisticated systems with world class penetration aid devices, a technology that was in part developed at Foulness (Dommett 2008, 110). As discussed above the characteristic structures associated with these later phases are the prefabricated buildings, commonly used as stores. Most of the later trials work was accommodated in existing structures or by their modification. Where temporary protected facilities were required Pendine blocks and armour plate could be speedily fashioned together to provide the necessary facilities. In the existing range areas a handful of reinforced structures were constructed in the 1960s and 1970s, including the buildings, **Firing Control and Instrumentation F6, Trials Recording F9, Instrumentation Building J10** and its **Compressor House J11**. The expansion of N Range during the 1970s probably reflects the diversification of the range's activities to include work not directly connected the nuclear weapons programmes, including the investigation of unqualified explosives and proof testing new munitions for service use. In the 1980s climatic testing of explosives, previously carried out at the Royal Arsenal, Woolwich, was moved to Foulness. This resulted in the construction of four new climatic testing buildings in the explosives area and minor modifications to some other buildings in this area.

The Range Structures

The former AWRE range at Fleet was purpose-built for the development and testing of the explosive components used in nuclear weapons. It was also closely associated with the study of the effects of nuclear weapons for civil defence purposes and on military equipment. In addition to these activities trials were also carried out on the range to support the civil nuclear programme, and in later decades a wide range of explosives and munitions testing. Due to the specialised nature of the establishment's activities many of the structures represent unique building forms.

Historically, the earliest range buildings were built shortly after the end of the Second World War in a time of an acute scarcity of building materials, of austerity and rationing, utility quality consumer goods, and power shortages. The earliest buildings constructed at Foulness in the 1940s are typically single storey brick structures with walls laid to stretcher bond and covered by flat asphalt reinforced concrete roofs. Typically, the window openings have concrete lintels and brick sills with metal-framed Crittall windows, in the range areas protected by single or doubled hinged steel shutters. Characteristically, sliding steel doors protect their outer wooden doors. Range control and instrumentation buildings also generally have a blank wall covered by armour plate, only pierced by small observation or camera ports facing the range areas. On

I and J ranges an unusual form of control and instrumentation building was built with trapezoidal walls, and an armour plated side facing towards the range. The largest building constructed at this date was a two storey office block in the headquarters area. This is of utilitarian appearance, although its entrance is distinguished by brick pilasters, a stone plaque recording 'A.R.E. 1949' and, at variance with the building's austere post-war character, above it is a large hexagonal bronze lantern.

In the Explosives Area the late 1940s structures are also brick built. A distinctive feature of these buildings is the use of copper-clad doors, a feature that reinforces their archaic appearance and is more in keeping with the 18th century powder magazines at Tilbury Fort than the dawn of the atomic age. Given, the large surplus capacity within the wartime factories, they also represent some of the few purpose-built explosives handling buildings constructed during the late 1940s.

Another feature of the late 1940s establishment was small observation or police posts dotted across the range. These are small square structures, probably for a single person. The lower section of these structures is brick built and capped by a reinforced concrete upper section pierced by narrow observation slits. In form they are similar to observation posts found in wartime Royal Ordnance Factories. These structures all appear to be of a standard form and might be presumed to be of similar date. Analysis of air photographs, however, suggests that they were built from the late 1940s and into the 1950s.

Given the widespread use of reinforced concrete during the war for a large range of protected structures it is perhaps surprising that more use wasn't made of this material at Foulness. The extensive use of brick in the late 1940s was probably a response to the shortages of steel and concrete, which despite its high national priority also affected this project. Perhaps to overcome the shortage of materials the establishment chose to draw on the local brickyards. This gave the establishment an outdated appearance that was out of keeping with its cutting edge technology, but in step with an era of austerity and utilitarian design. The first reinforced concrete structures did not appear until the early 1950s and after that date it became the standard material for range control and instrumentation buildings.

The decision in 1954 to proceed with a thermonuclear weapon, or H-bomb, marked the beginning of a large expansion in the number of buildings within the Headquarters Area. The urgency of the work at this time is reflected by the use of a contemporary prefabricated lightweight building system. These structures combined economy of materials with speed of erection, while presenting a contemporary industrial design. They were more in keeping with the establishment's cutting edge technology, and similar to structures erected at Windscale and Aldermaston. They are also comparable to other developments in public building projects, especially schools, where system-built designs were being widely used. Curiously, buildings constructed in the late 1950s reverted to brick construction, with Crittall windows, distinguished by concrete sills and lintels.

One of the largest buildings constructed during the mid-1950s was the new **Canteen**

and Common Room AI. This is a visually arresting building designed in a contemporary architecture style, with large glazed windows contrasting with solid brick end bays, which dominated the southeast corner of the administrative area. Internally, its layout clearly reflected the rigid civil service hierarchies of the 1950s, and of contemporary British industry and society. To the east is the main entrance for most of the workforce leading from a porch area into a large open airy dining room floored in a chequer board pattern of blue and white tiles. To the rear, separated from the dining room by a partition decorated with copper panels decorated with embossed abstract designs is a carpeted bar area. Also at the rear of the building was a smaller dining area for the senior staff, this has a dedicated entrance to the west and is distinguished by its wooden parquet flooring.

During the early 1950s the Explosives Area was expanded. Structures built at this time include three small explosives processing buildings. In common with the late 1940s explosives buildings it is also relatively rare to find new explosives handling buildings from the 1950s. The only other field where they are found is at sites associated with post-war rocket propellant research, such as at Westcott, Buckinghamshire and at Summerfield, Kidderminster. The Foulness explosives area was built to support the range's research activities, and in comparison to other service explosives production facilities the buildings are relatively small. They were also designed to undertake processes not generally needed in normal munitions production, namely the casting and machining of high explosives. In form the buildings are L-shaped and incorporate a rear reinforced concrete wall that effectively acts as a protective traverse. They were built in two phases, over 1951-52 and in 1955. The later ones are particularly well-finished with a washed gravel effect rear wall, sills and lintels, and teak doors.

In addition to the permanent range structures extensive use was made of portable and semi-portable structures. These included wooden-framed and aluminium trials cabins that could be placed on flat-bed trucks and demounted as required. A number of these may have been used on overseas trials and behind the glazed windows they are equipped with sliding fine copper gauze window screens to protect against insects. Probably during the 1970s or 1980s these were joined by a number of small, steel modular cabins, known as Wernick shelters (after their manufacturer).

Also dotted around the range are also a number of heavily armoured camera and instrumentation posts. There is no standard form to these structures, some are small armour plate cabins with bulkhead type doors and movable steel plates through which cables could be run. Other cabins appear to have been constructed from sections of fuel tanks. Also scattered across the range are 3 ft (0.9m) square steel plate explosives lockers that could be moved between the trials areas. As described above, large rectangular concrete blocks with lifting lugs on their top surface, known as Pendine blocks after a range in Pembrokeshire, were used extensively at AWRE Foulness. They were also used to provide temporary shielding, and in combination with armour plate used to create heavily protected test areas or structures.

During the 1960s breeze block was widely used in the construction of small ancillary buildings. Towards the end of the decade and into the 1970s there was an increase

of activity probably linked to the *Polaris* warhead upgrade programme, which would eventually lead to the *Chevaline* system. The building type most closely associated with period is the standard, commercial, prefabricated concrete panel garage with a corrugated asbestos roof and were extensively used for stores buildings. To supplement the late 1940s observation posts small, prefabricated concrete panel single person observation posts were also added. The few buildings constructed during the 1980s were steel-framed and covered in pressed steel sheeting. Extra accommodation was also provided by standard commercial portacabins and steel shipping containers.

Summary

The former Atomic Weapons Research Establishment (AWRE) at Foulness is one of a handful of sites associated with the United Kingdom's nuclear weapons programmes; other sites include the Atomic Weapons Establishment (AWE) Aldermaston and its close neighbour at Burghfield, both in Berkshire, and the former outstation at Orford Ness, Suffolk, the latter now owned by the National Trust. The research activities at Foulness spanned the full period of the Cold War and beyond, from the beginning of construction in 1947 to the withdrawal of AWE in 1997. During this time work was undertaken on all Britain's nuclear weapons and research into the effects of nuclear weapons.

Politically, work carried out at the atomic research establishments stretched to the inner heart of successive post-war cabinets and reflected their aspirations to develop and maintain Britain's nuclear weapons capabilities. On Foulness' ranges work was undertaken to perfect the design of the explosives lenses for the Mark I nuclear warhead. In building **X6** the events leading up to Britain's emergence as a nuclear power were enacted. In the summer of 1952 the first live, British nuclear devices were assembled prior to being taken to the Monte Bello Islands, Australia, for detonation in *Operation Hurricane*. In 1954, Churchill's cabinet endorsed the decision to proceed with the development of the H-bomb, which was reflected by a massive building programme at Foulness. The success of this programme not only gave Britain a capability in this field, it also opened the door to Harold Macmillan's 'great prize' of renewed nuclear co-operation with the United States (Hennessy 2007, 124).

The site is also significant through its association with a number of scientific personalities. The most important of these was Dr, and later Sir and Lord, William Penney, a key member of the wartime Los Alamos atomic bomb project and leader of the team that developed Britain's atomic bomb. Roy Pilgrim, one of the Superintendents of the Foulness range, was another veteran of the Los Alamos and the post-war Crossroads tests. Dr Francis Walley, an expert on blast damage a member of the post-war mission to Hiroshima and Nagasaki, and later President of Institute of Civil Engineers, supervised blast experiments at Foulness. Lord Solly Zuckerman, one of the most influential post-war government scientific advisors, also made use of the range's facilities. Beyond the few known individuals, many other anonymous scientists, engineers, and support personnel laboured at AWRE Foulness and through their technical expertise were critical to the United Kingdom's Cold War defence strategy.

Technologically, the history of the establishment was intimately associated with two of

the most momentous military-scientific achievements of the post-war era – Britain's development of the atomic bomb and a few years later the hydrogen bomb. This expertise was of critical strategic importance and went to the centre of the country's Cold War defence and foreign policy. The facilities at Foulness Island also have a wider importance in the history of technology, as exemplars of the methodology of scientific investigation during the 1950s. At that time the investigation of many phenomena, including the properties of nuclear weapons, required the physical replication, or modelling, of the effect to be studied. In recent decades, the balance has shifted to the development of computer models to understand the material world. The AWE facilities also represent examples of the many specialised post-war research and development establishments constructed to support the United Kingdom's defence programmes.

Nationally and internationally facilities associated with the pioneering phase of nuclear weapons development are rare. The first structures at Foulness represent some of the earliest buildings erected for the assembly and testing of nuclear weapons, predating both Aldermaston and the United States Nevada Test Site by two or three years. In contrast to the state arsenals of the past, architecturally these Cold War structures are utilitarian and functional, but were built to support one of the highest national priority defence programmes. At the time they were built, similar research facilities were restricted to the two Superpowers and the United Kingdom. Physical legacies of these programmes also stretch to Australia and the Pacific.

The investigation of the establishment's physical fabric can only produce a partial history. Nevertheless, in a situation where documents have been destroyed, or are unavailable, and where veterans are constrained in what they might say, the built heritage of the range may be seen to offer one route to its history.

7 MACHINERY AND ARTEFACTS

Within the buildings of the AWE area, especially the Explosives Storage Area, there is an unusual degree of survival of plant and fittings. Due to the specialised nature of the activities undertaken at Foulness many of the machines and pieces of equipment were expressly produced for the establishment. Most date from the late 1940s, 1950s and early 1960s and have added historical significance owing to their association with Britain's nuclear weapons programme. The present survey of machinery and artefacts was restricted to gathering information on items that were visible through windows or open doors.

Nationally few artefacts relating to the manufacture and handling of explosives are preserved in museum collections. The Royal Gunpowder Mills, Waltham Abbey, Essex, holds the largest collection of such objects, including machinery from that site and a number of Royal Ordnance Factories that were demolished during the 1990s.

Most objects that have been associated with the manufacture or handling of explosives may be considered to be contaminated with residual amounts of explosives. Typically decontamination involves the object being thermally remediated, whereby it and its associated building will be cleansed by fire. At Waltham Abbey it was found that robust items, such as presses, are able to survive such treatment and are capable of restoration as static museum display items. In the United States it has been found that stripping painted machines back to bare metal by chemical methods is also effective in removing explosive residuals (*pers. comm.* Robert Howard, Wilmington, Delaware)

The greatest concentration of surviving plant is within the Explosives Storage Area.

Equipment includes water jacketed melting vessels used to melt high explosives which were used to cast different shaped charges. Examples survive in the **Casting Shop X10** (Figure 41) and the **Explosives Casting X34** building. Specialised and remotely operated machines for machining high explosives remain in the **Explosives Machining X13** and **X14** buildings, and perhaps in **X12**. An unusual design feature of a number of the buildings is the use of copper clad doors **Magazine X3**, **Magazine X4** and **Assembly/ Metrology Building X6**, **Explosives Casting and Pressing Laboratories X23/29**, and **Magazine X23A**.

In the **Explosives Preparation Laboratory X6**, most of its internal fittings survive, including, in the metrology room, a precision measuring table by Windley Bros Ltd, Chelmsford. Tables such as this were used to measure components before they were assembled into experimental charges or other devices. The devices for the 1952 *Hurricane* test were assembled in this building, but it is not known if this table was in place at that date. The surviving machines in **Explosives Casting and Pressing Laboratories X23/29** may be equated with those identified on a design drawing 16 December 1947 (TNA: PRO ESI/330). This was one of a series of designs approved by Roy Pilgrim at this time. They include, in Room 4, a Fly press by John Mills & Co (Llanidloes Railway Foundry), in Room 5, an 80 ton press, and, in Room 7, a 200 ton press and elsewhere an air compressor. They represent artefacts from some of the earliest AWRE activities on the site; it is believed that they were used to manufacture

charges for Civil Defence experiments. Equipment might also survive the **X-Ray Facility X40** and its associated **X-Ray Control Room X39**.

Within the **Structures Laboratory S5** (Figure 29) a stress testing machine and a few sections of test models that survive are associated with the specialised experiments carried out by this section.

In the headquarters area, the **Telephone Exchange A3** retains most of its internal communications equipment that was last used during the 1990s. In the **Main Mechanical Workshop E2** is at least one specialised milling machine and a trolley that appears to be for the free fall nuclear weapon WE177 (Figure 50). In the **Shock Tube Laboratory H8/70** (Figure 54) the shock tube and its associated tools remain in place. Also scattered across the range are a number of trials cabins that may have been used on overseas atomic trials work.

9 SURVEY AND RESEARCH METHODS

The documentary and historical sections of this report are based on an earlier desk top investigation of the site (Cocroft 2004), and the present report supersedes any conclusions within it. The historical section was prepared using readily accessible secondary sources, which are listed in the bibliography and sources. Primary document files relating to the weapons research at AWRE Foulness were consulted at the National Archives, Kew, and a selection of files describing work associated with Britain's civil nuclear programme were also seen. AWE Aldermaston also made a couple of recently declassified files available for inspection. A number of papers and photographs relating to experiments to assess blast effects on structures carried out at Foulness are held in the Dr Francis Walley collection at the Institution of Civil Engineers, Great George Street, London. The papers of Edward Drake Seager are held in the Liddell Hart Centre for Military Archives, King's College, London, and contain some information on the Buffalo weapons trials. The University of East Anglia, Norwich, preserves the private papers of Solly Zuckerman. These contain papers relating to his work on blast effects on the human body and the Buffalo trials. Historic Ordnance Survey maps and air photographs (held by the National Collection of Air photographs in the National Monuments Record) of the area were also studied.

Fieldwork was carried out intermittently during autumn 2006 and spring 2007. In the field external descriptions were made of all the accessible range buildings and features, which were recorded on standard forms. Due to the lack of a land quality assurance report on the surrounding pasture it was not possible to walk over these areas. To investigate these areas they were transcribed by Helen Winton from historic air photographs using the University of Bradford Aerial5 photo rectification program. Control information was taken from the Digital copies of current OS 1:2500 maps. All digital transformations are accurate to within 5m of true ground position, and typically less than 2m to the base map. The transcription was produced in AutoCAD by tracing the archaeology from the transformed and georeferenced aerial images.

The predominance of pasture in much of the survey area, and the tendency to water-logging, may hamper the potential for discovery of archaeological remains through cropmarks. However, where periods of arable cultivation were recorded on the air photographs many of the substantial features, such as drains and realignments of the sea defences can be seen in places as cropmarks, in particular on photographs taken in April 1996. No features could be positively identified as earlier in date than post medieval.

All readily available air photographs from the NMR collections were consulted. The main sources used for the mapping were the runs of vertical photographs taken on the 1st and 10th May 1946. These gave an invaluable record of the structures and buildings demolished or removed in the late 1940s. These were supplemented by high quality verticals taken in the mid 1950s, which clearly show those post-medieval earthworks that have not been obscured by AWRE buildings or damaged by post war weapons testing. Earlier aerial mapping in the area by the National Mapping Programme only recorded some oyster pits along the creek edges and did not include any Second World War features. The results of the air photographic transcription have been incorporated into

this report. An unedited version of the results of the transcription is included in the site archive. The air photographic survey revealed that for the area of the whole of the Shoeburyness ranges, there is enormous untapped potential in the collection of historic air photographs held at the NMR. In particular, they record the physical remains of structures relating to Second World War, the majority of which have no record in the NMR, Historic Environment Record or Defence of Britain databases. A list of the key photographs used in the air photographic transcription is contained in the Bibliography and sources.

To accompany this report is a collection of professional papers providing a brief description and historical summary for each structure on the range. A hard copy is deposited in the National Monuments Record. The site archive and copies of this report will be deposited in the National Monuments Record, Great Western Village, Kemble Drive, Swindon, SN2 2GZ.

10 CORRELATION OF HISTORIC RANGE NUMBERS WITH CURRENT LETTERS

Mid-1950s	Current
Range 1	C, D and F Ranges
Range 2	J Range
Range 3	I Range (extreme southwest end)
Range 4	I Range (northeast end)
Range 5	S Range (structures area)
Range 6	I Range (west of I/SF87)
Range 7	J Range (west end)
Range 8	K Range
Range 9	K Range (west side)
Range 10	N Range (west side)
Range 11	N Range (east side)

Information derived from TNA: PRO ABI6/1777

II CORRELATION OF ORIGINAL TO CURRENT NUMBERS

Proposed completion dates of 1 January 1948, 1 April 1948 and 1 June 1948 are given; these may refer Phases I-III, a table attached to memo date August 1947 lists a few additional buildings which may correspond to Phase IV, modifications in memo dated 29 December 1947 are termed Phase IVa.

	Later #	
1	C1	Recording building – large bomb range – <i>Phase II</i>
2	D1	Recording building, including photographic – <i>Phase III</i> – modified to Chemical Analysis Laboratory – <i>Phase VII</i>
3	II	Main recording building – <i>Phase I</i>
3a	II	Shock tube building (Civil Defence, etc) – <i>Phase I</i>
4e	I7	Fragment analysis – <i>Phase IV</i>
5		Instrument Laboratory – <i>Phase IV</i>
6		Recording and calibration of pressure gauges – <i>Phase I</i>
7		Recording building – small bomb range – <i>Phase II</i>
8	K3	Very high speed recording – <i>Phase I</i>
9	S4	Structural analysis laboratory (Concrete Civil Defence) – <i>Phase II</i>
10	A2	Headquarters Block – <i>Phase I</i>
11	A4	Photographic including processing and projection – <i>Phase I</i>
12		?
13	?J7	Field photography laboratory – <i>Phase I</i>
14		Machine shops and electrical stores – <i>Phase I</i>
15		?
16	A10	Garage – <i>Phase I</i>
16a		Fuel store – <i>Phase III</i>

- 16b Vehicle inspection ramp – *Phase II*
- 17 X20 Bomb and shell store – *Phase III* – modified to Process building – *Phase VII*
- 18 X23A Powder store – *Phase III*
- 19 X21 Bulk HE and bare charge store – *Phase I* – modified to process building
Phase VII
- 19a Process Laboratory – *Phase VII*
- 20 X20 Detonator store – *Phase I*
- 21 X4 Fuze and flash store – *Phase III*
- 22 X3 Store for munitions which may not be stored in other explosives stores
(also referred to as Special Store) – *Phase III*
- 23 X6 Explosives preparation laboratory, charge hand's office – *Phase II*
- 23a X5 Non explosives components store – *Phase IVa*
- 24 A7 Canteen – *Phase I*
- 25 S5 Concrete preparation and control (Civil Defence, etc) – *Phase I* –
modified *Phase XI* now designated S5 Concrete Laboratory
- 25a S1 Aggregate store – *Phase I*
- 26 ?X26 Quarters for resident police guard – *Phase I*
- 27 ? I /SF3 Tank for underwater experiments – *Phase III*
- 28 Police lodge – *Phase IV*
- 29 X23 Explosives casting and pressing laboratories – *Phase IVa*
- S3 Splinterproof for camera – *Phase II*
- S4 Splinterproof for camera – *Phase II*
- S5 Splinterproof for camera – *Phase I*
- S6 Splinterproof for camera – *Phase II*

S8 Splinterproof for camera - *Phase III*

Buildings located from map in TNA: PRO ABI6/I777

33 F1 Range I
34 K4 Range 8
35 F4 Range I
36 ?J3 Range 7 ?instrumentation/firing control
37 Range 5 Control Bunker Civil Defence range
44 Range I
45 Main gate
46 Range I
48 Main gate

Identified from field observations

40 H2 Offices
41 E11 ?Store
47 E11 ?Workshop
49 H3 Offices

Buildings constructed Phases V-XVI 1949-1956, sources TNA:PRO ESI/268, ESI/269

41 Store, HQ area – *Phase V*
50 Stores Building – *Phase VI*
51 Lavatories, Darkroom - *Phase VI*
52 Drawing Office – *Phase VI*
53 ?C2 Amenities Building – *Phase VI*
54 X7 Entrance Dirty and Clean area – *Phase VI*
55 X9 Machining Building – *Phase VI*

56	X10	Casting Building – <i>Phase VI</i>
57	X11	Machining Building – <i>Phase VI</i>
58	N1	Recording Laboratory – <i>Phase VII</i> – Range II
59	N2	Recording Laboratory – <i>Phase VII</i> – Range II
60	T1	Motor Transport Office and Amenities – <i>Phase VII</i>
61	T2	Motor Transport Workshop and Building – <i>Phase VII</i>
62	T3	Oil Store – <i>Phase VII</i>
63	T7	Petrol Kiosk – <i>Phase VII</i>
68	E14	Timber Store – <i>Phase VII</i>
69		Compressor House – <i>Phase IX</i>
70		Atomic Blast Simulator – <i>Phase IX</i>
71	?H7	Firing Chamber – <i>Phase VIII</i>
72	H8	Large Shock Tube – <i>Phase VIII</i>
73		Office Laboratories, Fort Halstead Group – <i>Phase VIII</i>
74	E16 or E23	Calor Chamber – <i>Phase VIII</i>
75	E16 or E23	Calor Chamber – <i>Phase VIII</i>
76		Trials Store – <i>Phase VIII</i>
77		Laboratory – <i>Phase IX</i>
78		DGS – <i>Phase IX</i>
A1		Canteen – <i>Phase XII</i>
D3		Splinterproof Building – <i>Phase XI</i>
E1		?Design Office – <i>Phase X</i>
E2		Machine Workshop – <i>Phase X</i>
E3		Stores Shed – <i>Phase X</i>

E4	Boiler House – <i>Phase X</i>
L1	Laboratory – <i>Phase X</i>
L2	Laboratory – <i>Phase X</i>
L3	Laboratory – <i>Phase X</i>
L4	Laboratory – <i>Phase X</i>
L5	Laboratory – <i>Phase X</i>
L6	Electronics Laboratory –
ML2	Explosives Store – <i>Phase VII</i>
M3	Explosives Store – <i>Phase VII</i>
M4	Magazine Locker – <i>Phase XI</i>
S4, D34	Structure Laboratory – <i>Phase XI</i>
X1	Office – <i>Phase XI</i>
X2	Chemical Laboratory – <i>Phase XI</i> (was 2?)
X12	Process Building – <i>Phase XI</i>
X13	Process Building – <i>Phase XI</i>
X14	Process Building – <i>Phase XI</i>
X29	Alteration – <i>Phase XI</i> (was 29?)
X34	Casting house

Information derived from TNA: PRO ABI6/1777; ESI/267, ESI/268, ESI/269 and field observations.

II DOCUMENTED EARLY PHASED DEVELOPMENT OF AWRE FOULNESS

Sources TNA:PRO AB 16/1777, ESI/267, ESI/269, ESI/331 Zuckerman Archive SZ/BUF/3/2 Buffalo Documents 2, dates often relate to the initial development proposal, construction often took place a year or so later. In this section if the current number is known it is given in square brackets [].

Phase I 1947 Main Recording Building 3 [I1], Shock Tube Building (Civil Defence, etc 3a [I1], Recording and Calibration of Pressure Gauges 6, Very High Speed Recording 8 [K3], Headquarters Block 10 [A2], Photographic including Processing and Projection 11 [A4], 12, Field Photography Laboratory 13 [?J7], Workshops and Stores 14, ?15, Garage 16 [A10], Bulk HE and Bare Charge Store 19 [X21], Detonator Store 20 [X20], Canteen 24 [A7], Concrete Preparation and Control (Civil Defence, etc) 25 [S5], Aggregate Store 25a [S1], Quarters for Resident Police Guard 26 [?X26], Splinterproof for Camera S5

Phase II 1947 Recording Building (large bomb range) 1 [C1], Recording Building (small bomb range) 7, Structural Analysis Laboratory (Concrete Civil Defence) 9 [S4], Vehicle Inspection Ramp 16b, Explosives Preparation Laboratory 23 [X6], Charge Hand's Office, Splinterproofs for Cameras S3, S4, and S6.

Phase III 1947 Recording building, including Photographic 2 [D1], Fuel Store 16a, Bomb and Shell Store 17 [X20], Powder Store 18 [X23A], Fuze and Flash Store 21 [X4], Store for Munitions which may not be stored in other explosives stores (also referred to as Special Store) 22 [X3], Tank for Underwater Experiments 27 [?I/SF3], Splinterproof for Camera S8

Phase IV 1947 Fragment analysis 4e [I7], Instrument Laboratory 5, Police Lodge 28, Explosives Casting and Pressing Laboratories 29 [X23]

Phase IVa 1947 Non Explosives Component Store 23a [X5]

?Phase V 1949 Building for Gauge Development Section, extension to existing Shock Tube, additional Store in Headquarters Area ?41 [E11], Concrete Shelter for Industrial Staff, additional building on Range 1 for Special Photographic Equipment

Phase VI 1951/2 Stores Building 50, Lavatories, Darkrooms 51, Offices & Drawing Office 52, Amenities Building 53 [?C2], Entrance Dirty and Clean Area 54 [X7], Machining Building 55 [X9], Casting Building 56 [X10], Machining Building 57 [?X11]

Proposed after the decision to proceed with a thermonuclear device

Phase VII 1954 Process Laboratory 19a, Recording Laboratories 58 [N1], 59 [N2], Motor Transport Office and Amenities 60 [?T1], Motor Transport Workshop and Building 61 [?T2], Oil Store 62 [?T9], Petrol Kiosk 63 [?T7], Timber Store 68 [E14], Explosives Stores M2 & M3

Phase VIII 1954 Firing Chamber 71, Large Stock (?sic Shock) Tube 72 [H8], Office Laboratories 73, Calor Chambers 74 & 75 [E16 and E23], Trials Store 76, roads, sewage plant, telephone system

Phase IX 1955 Compressor House 69, Atomic Blast Simulator 70, Laboratory 77, DGS 78

Phase X 1955 Laboratories LI-5, ?Design Office EI, Workshop E2,

Stores Shed E3, Boiler House E4

Phase XI 1955 Office XI, Chemical laboratory X2, Press Buildings X12-14, Alterations to X29, Magazine Locker M4, Splinterproof Building D3, Structure Laboratory S4, D34, Concrete Laboratory S5

Phase XII 1955 Additional Administrative Facilities for the Headquarters Area new Office Block A6, enlarged Canteens and Common Room AI, ?Surgery

Phase XIII 1955 Infrastructure, drainage and static water supply, including Shelford dam

Phase XIV ?

Phase XV 1956 Boiler House, 2 Bomb Chambers Structures Laboratory, 2 Tubular Towers

Phase XVI 1956 Surgery A5, Solvent Store, Plant Store, Police Lodge ?Q/PP3, Clocking Station

Electronics Laboratory L6

12 CHRONOLOGY

- 1942 Armament Research Department (ARD) formed
- 1945 August United States dropped atomic weapons on Hiroshima and Nagasaki
- 1946 Nov United States passes Atomic Energy Act (McMahon Act), effectively ending the interchange of nuclear information with the United Kingdom
- 1947 8 Jan A small committee of Attlee's ministers decided that the United Kingdom should develop an atomic bomb
- June 'High Explosives' division established at Fort Halstead, Kent, known as Basic High Explosive Research (BHER), later abbreviated to High Explosive Research (HER)
- 1948 Armament Research Department became the Armaments Research Establishment (ARE)
- 1950 The former RAF airfield at Aldermaston, Berkshire, was taken over as the headquarters for the British atomic bomb programme
- Administrative links between HER and ARE were broken
- 1952 June First British atomic devices, *Hero*, *Hengist* and *Horsa*, were assembled in Building 23, Foulness
- 1 Aug Plutonium core for the *Hurricane* device was completed at Aldermaston
- 3 Oct First United Kingdom atomic device detonated in *Operation Hurricane* at Monte Bello Islands, Australia, it had a yield of 25 kilotons
- 1953 12 Aug Soviet Union detonated her first megaton weapon
- Nov First British atomic bomb *Blue Danube* issued to the RAF Bomber Command Armament Training School at RAF Wittering
- 1954 Responsibility for atomic matters transferred from Ministry of Supply to the newly created United Kingdom Atomic Energy Authority
- 16 Jun Defence Policy Committee authorises the Ministry of Supply to produce thermonuclear weapons
- 26 Jul The Cabinet endorses the decision to proceed with the development of a thermonuclear weapon
- 1955 1 Jan UK announced its intention to develop thermonuclear weapons

Armament Design Department and Armament Research Establishment combined to form the Armament Research and Development Establishment (ARDE)

22 Nov Detonation of first Soviet true fusion bomb with a yield of 1.6 megatons

Blue Danube weapons might be considered for service use with Valiant aircraft based at RAF Wittering.

1956 August/September *Buffalo* series of trials at Maralinga, Australia

1957

May *Grapple* series of tests at Christmas Island begin

1 Oct Accidental detonation of around 1,500 lbs of TNT on the Foulness burning ground

4 Oct Soviet Union launched the first artificial satellite *Sputnik*

10 Oct Fire in the Windscale plutonium piles

8 Nov *Grapple X* Detonation of Britain's first 'true' H-bomb 1.8 megatons

1958 Mutual Defence Agreement signed with United States, agreeing to the sharing of certain information on nuclear weapons

1962 8 Feb ARDE granted title of Royal Armament Research and Development Establishment (RARDE)

1963 Partial Test Ban Treaty - banned nuclear tests in the atmosphere, underwater and in space – not signed by France or China

1967 Polaris warhead improvement programme initiated – various codenames for warhead options *Super Antelope*, *HRI69*, *KH793*, finally designated *Chevaline* in 1974

1973 AWRE was transferred to the Procurement Executive in the Ministry of Defence

1982 First *Chevaline* warheads entered the UK nuclear warhead stockpile

1987 1 Sept The Atomic Weapons Research Establishment (AWRE) merged with the Directorate of Atomic Weapons Factories (DAWF) and became the Atomic Weapons Establishment (AWE)

1991 1 Apr Defence Research Agency (DRA) formed from a number of government

establishments including RARDE

- 1993 Management of part of the Foulness site was transferred to the Defence, Research Agency, which became part of the Defence, Evaluation and Research Agency (DERA) in 1994.
- 1996 *Chevaline* withdrawn from service
- 1997 AWE withdrew from Foulness
- 1998 March Last WEI77 free fall nuclear weapon withdrawn from RAF service.
- 2002 QinetiQ assumed control of most of DERA's activities

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